

Proceedings of the



16th LONDON SWINE CONFERENCE

A Platform For Success

April 5-6, 2016

London, Ontario

www.londonswineconference.ca



PROCEEDINGS

of the

LONDON SWINE CONFERENCE

A PLATFORM FOR SUCCESS

Edited by
J.H. Smith and L. Eastwood

April 5th and 6th, 2016

London, Ontario

www.londonswineconference.ca

Proceedings of the London Swine Conference
A Platform For Success

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ISBN 978-1-927026-05-2

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A Platform for Success

Tuesday April 5 • SOW FOCUS & Wednesday April 6 • W-F FOCUS

Chair's Message



Through creation of a "Platform for Success," the London Swine Conference provides a forum for the exchange of credible, science-based information for decision-makers and influencers in the pork industry. We want the platform to encourage the exchange and adoption of knowledge for the betterment of your farm, agricultural business and the entire pork value chain.

I want to welcome you to this premier Ontario conference. We begin with Rob Saik's *Agricultural Manifesto*, as he looks at drivers shaping agriculture over the next decade—a topic which will challenge us all. Presentations today will concentrate on sows and gilts, and tomorrow our focus is on wean to finish. Regardless of your role in the swine industry or your size of production, these speakers and participants all have valuable information to share. Whether it's bridging workplace gaps between generations (*Managing Generational Expectations*), understanding the overlap between use and overuse of antibiotics (*Antimicrobial Resistance: Myths and Realities*), animal health (*Managing the Health Status of the Sow*), or performance issues in your barn (*Solutions to Productivity Challenges*), there is much to be learned here. Our format of plenary and breakout sessions gives you the chance to ask questions of and challenge our presenters who in turn will provide you with the latest information and research results.

Listen. Engage. Take home new ideas. We have created a platform for sharing and learning that will help grow and improve your business. Learn not only from our outstanding lineup of speakers, but from each other with networking opportunities following each day's formal sessions.

I would be remiss not to thank the outstanding group of professionals who have worked together to bring you this conference and make my job easy. They have provided a Platform for Success from which I know you will gain a wealth of knowledge.

Doug Ahrens,
Steering Committee • 2016 London Swine Conference

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London Swine Conference • A Platform for Success, April 5 and April 6, 2016

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We look forward to seeing you again in 2017.

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Day 1: Sows – Main Sessions

THE AGRICULTURE MANIFESTO

Rob Saik

The Agritrend Group of Companies

rsaik@agritrend.com

SUMMARY

Agriculture is no longer Murray McGlaughlan's "dusty old farmer bent over the tractor wheel" but a full-fledged modern business integrating all the tools available to it.

We will look at how Science and Technology are being integrated with modern agricultural practices to provide society with a safe, reliable food supply in an environmentally sustainable manner AND we will look at some of the threats that could potentially erode our ability to feed the people on the planet.

There are major technology currents pulling on all of humanity. We can choose to fight the current or be aware of their strength and swim in the same direction...and be ahead of the competition.

Rob will take you on a quick journey showing how farmers are integrating technology to feed a growing world population. He will touch on exponentially, robotics, artificial intelligence, sensor integration, bio synthesis (GE and GMO), data systems and environment sustainability.

Finally, we will look at HOW we could integrate all these technologies to best serve our farmer customers through new business opportunities offered by our dealerships.

And lastly, you will walk away with a sense that, in spite of what the media reports, things are actually pretty good and getting better all the time.

PARITY 3 ROADBLOCK

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ABSTRACT

The proportion of sows in the breeding herd that fail to remain beyond their third parity can result from single or multiple factors that may interact and lead to culling. Most of the reasons for culling reside in the involuntary category with the leading reasons involving reproductive failure and poor litter performance. Although other issues such as locomotor problems are prevalent, this paper will focus on reproductive and litter failures, which collectively account for 60% of all cullings. Factors associated with culling alone and in combination with other risk factors include young parity, excessive weight loss in lactation, season, short lactation length, improper boar exposure and single service. These and other issues have each contributed extensively to culling. Approaches to minimize culling due to these factors, in essence, means that individual farms will need to identify their leading risk factors and take a proactive approach to correct the issue and monitor positive changes. Understanding the types of risk factors that associate with specific cases of fertility failure in sows will require records in critical areas related to management in the reproductive lifetime of the female.

RETENTION AND CULLING

The investment in a breeding female involves the purchase of her genetic value, costs for growth and health care, housing, and labour. The return on the investment occurs when she is able to produce a 3rd litter of pigs with minimal non-productive days. In addition, peak productivity lies with higher parity sows, since the largest litters of pigs are produced in parities 3 to 5 (Rodriguez-Zas et al., 2003). Further, as sows mature, they produce more milk, provide better immunity, and wean heavier litters. Culling is a necessary part of breeding herd management, with animals removed from the herd for voluntary reasons associated with old age and low performance and for involuntary reasons such as extended wean to service intervals, reproductive failure, lameness, and poor body condition (Carroll, 1999). Voluntary culling based on total sow inventory should be 30% for old age (or 68% of all culls), 10% for reproductive failure (or 23% of all culls), and 4% for unsoundness (or 9% of all culls). This would sum to a targeted annual culling of 44%. However, culling rates vary greatly among farms. Data over a number of years has shown culling rates increasing, which now commonly reside at 50% or more. What is concerning is that with higher culling, 40-50% of the females are removed before they reach their 4th parity. Higher culling rates in parity 1-3 sows, means that fewer sows will advance on into the higher parities, leading to their replacement with less productive gilts (Houska et al., 2004). Herd parity structures have been modeled on ideal retention and replacement rates for modern commercial production. Recommendations suggest maintaining a non-serviced gilt inventory within 3-5% of total sow inventory, ~33% of the herd in the P0 to P1 class and 50% or more in the P2 to P5 classes, with the remaining herd in the higher parities. This type of herd structure places the greatest proportion of sows in the most productive parities. At high levels of culling, it is not possible to maintain these levels to

optimize production targets (Figure 1). It can be seen in the Figure that at a culling rate of 65%, more gilts are bred and enter as P0, with fewer later parity sows maintained. At the targeted 45% culling rate, the ideal parity structure is shown in Figure 1 and also described in Table 1. From the Table it can be seen that as retention rates decline in the higher parities and cull rates increase, more emphasis is placed on replacement gilts to make up the difference.

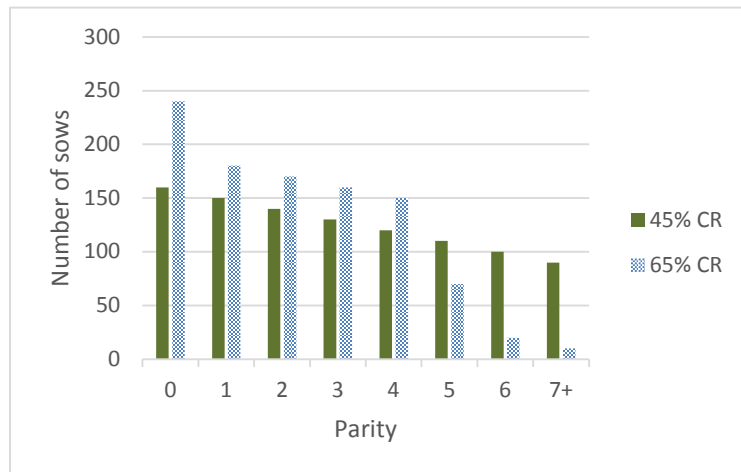


Figure 1. Distribution of sows modeled on an ideal (average) annual culling rate of 45% or higher culling rate such as 65% based on a 1000 sow farm (adapted from PIC).

Table 1. Targeted parity distribution, retention and culling rates.

	P0 (mated)	P1	P2	P3	4	5	6	7+	
Targeted herd parity (%)	16	15	14	13	12	11	10	9	100%
Example for 1,000 sows	160	150	140	130	120	110	100	90	1,000
Average retention rate	94%	88%	84%	80%	76%	72%	67%	58%	
Average cull Rate	6%	12%	16%	20%	24%	28%	33%	42%	
Retained sows	160	150	132	111	89	67	49	32	790

Adapted from Ketchum and Rix, National Hog Farmer, 2013 and PIC Sow and Gilt Management Manual (2013).

In data sets that have observed similar culling patterns, Lucia Jr et al. (2000) indicated average parity at removal was 3.3 with the leading reasons for removal identified as reproductive disorders (34%), poor litter performance (21%), and locomotor problems (13%). It is interesting to note that sows culled for reproductive failure also accumulated the greatest number of non-productive days which would accumulate from anestrus, extended wean to service intervals, and conception failures. Of those culled for reproductive failure, approximately 36% were P0 with reasons for removal led by conception failure (40%), fail to farrow (33%) and anestrus (27%). Culling for locomotor

problems averaged 13%, but was noted to be as high as 20% in gilts (Table 2). Of importance, the addition of reproductive failure with litter problems together account for 50-60% of all cullings in parities 0 through 6.

Table 2. Reasons for removal (%) of ~8,000 records from PigCHAMP (modified from Lucia et al. 2000).

	Parity				
	0	1	2	3	4
Reproductive disorders	36	19	12	10	8
Litter failures	-	11	14	15	17
Miscellaneous	19	16	13	13	13
Locomotor	20	20	15	14	10
Old age	0.4	0.1	0.4	1.3	2.9
Death	14	14	16	14	14
Disease/peripartum problems	13	15	14	11	15
TOTAL	19	15	12	11	11

REPRODUCTIVE FAILURE

Classifying the type of reproductive failure can help farms focus on areas of reproductive management to alleviate cases of involuntary culling. In one assessment, the major causes of involuntary culling were attributed to anestrus, extended wean to service interval (WSI), conception failure, and failure to farrow. Anestrus and extended WSI are associated with excessive body condition loss in lactation, season of the year, parity, ineffective boar exposure, housing stress, and problems with partial litter removal. Conception failure can be associated with poor semen quality, less skilled breeding technician, improper number and timing of AI services, season of the year, stress, parity, wean to service interval, and in some cases, interaction with genetics. What is interesting to note from Table 2 is that several of the causative factors can impact the same reproductive response. What this suggests is that when attempting to solve reproductive or litter failures, awareness of multiple sources for problems should be considered.

Table 2. Major factors associated with reproductive failure and poor litter performance.

	Reproductive Failure			Poor Litter Performance	
	Anestrus	WSI	Conception	Total born	Poor lactation and litter quality
Partial weaning	x	x			
Lactation feed intake and BCS	x	x	x	x	x
Sow Parity	x	x	x	x	
Season of the year	x	x	x		
Housing stress	x	x	x		
Boar exposure issues	x	x			
AI technique			x	x	
Semen fertility			x	x	

For reproductive failures classified as estrus and conception failures, each has been associated with specific areas of farm reproductive management. From survey data, differences among farms were reported for weaning age, seasonal infertility, culling rates, farrow rates, application of boar exposure, and time of re-breeding and pregnancy diagnosis (Knox et al., 2013). Each has been shown to impact herd productivity and fertility measures for estrus and conception. In groups of weaned sows, there is expected to be a small distribution for length of lactation, but problems may arise with very short and even very long lengths which can affect ovarian status and function. Although the majority of sows may be in the “normal range”, those outside this window are more likely to experience infertility issues such as failure to develop follicles and express estrus, and failure to express estrus if they cycle during lactation. The best way to prevent problems is to maintain tight breeding groups and farrowing groups for all in all out management.

Many farms report seasonal infertility in summer and into fall, but the extent of failure and how it is observed may vary among farms. Farms report extended WSI, lower conception rates, and more returns to service in seasons. This also appears to be more related to risk factors in the lower parity females. It is very possible that accumulating risk factors of excessive body condition loss, especially in lower parity females within season, predisposes young sows to culling. Season has been linked with reduced farrowing in summer and into autumn compared to winter-spring seasons with more pregnancy losses and lower total born, especially in those with a WSI greater than 6 days (Lopes et al., 2014). The origin of the pregnancy loss and even lower litter size may be associated with problems in follicle development and less developed oocytes in certain seasons (Bertoldo et al., 2010).

The effects of housing stress for weaned sows has recently gained a lot of attention for reproductive performance and welfare and is important for longevity as it may interact with parity and season. The success or failure of reproduction in any housing system for weaned sows can be complex and influenced by many factors such as type of feeding system, pen layout and design, dynamic or static grouping, and numbers of sows per pen, to name a few. Tests of when to group sows relative to weaning or time of last service have been of interest. While there seems to be no consensus at this time on what approach is best or worst, studies do suggest some effects of time of grouping on behavior, welfare and in some cases fertility (Knox et al., 2004; Knox and Estienne, 2013; Knox et al., 2014; Rault et al., 2014).

Wean to Service Interval

Problems associated with delayed return to estrus after weaning have been linked to season, parity, body condition, and problems in lactation. There is evidence that in some circumstances, split weaning may cause lactational ovulation and delayed service following weaning (Terry et al., 2013). From this report, 3-7 pigs were split-weaned on day 18 with the remaining pigs in the litter allowed to continue nursing. The application of split weaning with boar exposure during lactation induced 70% of sows to express estrus within 5 days (day 23) while boar exposure alone induced 35% to express estrus by that time. What is also interesting from an industry survey (Knox et al., 2013) is the variation in when and how boar exposure is applied for weaned sows. This variation could help explain problems such as extended wean to service intervals and cases of anestrus, and could even relate to conception and litter size problems attributed to improper number of

services and poor AI timing. In weaned sows, failure to return to estrus has been associated with short lactation length, ovarian cysts, low parity, and season (Knox and Rodriguez-Zas, 2001). Ineffective boar exposure can result in delayed follicle development and extended service intervals (Kemp et al., 2005). Considerable evidence is also available to suggest that females that receive a single service are more likely to show conception failure (Lamberson and Safranski, 2000), and reduced numbers of pigs born alive, with gilts more likely to receive one service compared to sows (Takai et al., 2009). The increase in frequency of single service is most likely related to shorter periods of estrus for gilts mated too young (150-222 days) and too old (>260 days) and for sows with an extended wean to service interval (Takai et al., 2009).

Re-breeding Performance

There is a considerable body of work to illustrate that the fertility of females that are re-served after a first time conception failure have a much higher risk of subsequent reproductive failure. This is important and suggests that a portion of first time failures are indicative of inherent female fertility failure. Collection of management information could help identify what factors might be associated with first time failures in these high risk animals and which steps might be used to improve retention and performance. Farms show considerable variation in how and when they diagnose conception and when decisions are made to cull or keep after a first conception failure. More precise assessment for reproductive status in addition to use of records for female measures, could improve the timing for decisions on re-breeding or culling.

POOR LITTER PERFORMANCE

Reasons for culling include low total born, low born alive, and problems during the farrowing process, especially in gilts. In addition, low number of pigs weaned and low weaning weights also lead the reasons for culling as a result of poor lactation performance, or poor mothering ability. Total born litter size results from a series of events starting with ovulation rate, fertilization rate, embryo survival and uterine capacity. Ovulation rate appears to be most affected by feed intake in lactation, while fertilization rate of the number of eggs ovulated, can be affected by technician performance in detection of estrus, timing of inseminations, and the fertility of the sperm. Our understanding of embryo survival is still not entirely clear, but fetal survival is most related to the uterine capacity of the female and is affected by her genetic composition, parity, and state of the reproductive tract. Born alive is the measure of fully formed pigs that survive the birth process. Stillborn pigs likely account for most of the reduction in born alive. Most stillborn pigs are born dead as a result of hypoxia, which results from an increased time interval in the birth canal without adequate blood supply from the mother. This often occurs to the first and last pigs born in the litter and therefore appears to be a result of uterine contractions and a small birth canal at the start of farrowing and at the end of farrowing, the uterus becomes less contractive due to uterine fatigue. These and other types of problems at birth, such as uterine prolapse, often result in culling.

Causes

Poor feed intake in lactation can cause a host of reproductive problems, with notable effects on return to estrus, subsequent litter size, and poor litter weaning weights. Parity 1

sows are known to have lower born alive and while the origin of this is unclear, these females have lower backfat in gestation and lose more backfat in lactation, compared to older sows (Škorjanc et al., 2008). There have also been reports of a decline in second parity litter size. This problem is likely a result of the mobilization of body reserves during first lactation as a result of excessive weight, body condition, protein and fat loss (Schenkel et al., 2010). One approach that has been successful for improving litter size in the second parity has been to delay service using either a progestogen feeding program or a simple skip heat breeding protocol (Werlang et al., 2011).

Poor lactation and weaning performance are most often associated with problems in sow feed intake in lactation. This can result from problems with feed management in gestation and mis-management of body condition. The end result is that lactating sows do not consume the required amount of feed to maintain body condition and optimal milking performance. With poor sow feed intake patterns, litter weight gain is less than optimal. Studies have shown that average daily feed intake during lactation should be at least 6.2 kg/d. This may be a challenge in many circumstances but wet feeding is reported to improve intake 7-10% compared to dry feeding with *ad libitum* access during the last 2 weeks of lactation (Lawlor and Lynch, 2007). Improving water intake or access is also important for improving lactation feed intake and minimizing body weight loss as water intake has been shown to increase from farrowing until day 16 (Kruse et al., 2011). The risk factors associated with sows culled after weaning included those nursing a larger litter, reduced lactation feed intake, and low backfat at weaning. In fact, sows consuming <3.5 kg/day during any day throughout weeks 1-2 of lactation were more likely to be culled before the next parity. Sows with the highest odds for removal were those that consumed no feed on any single day during lactation, compared to those that consumed an average of 6.9 kg/day. During lactation, sows consumed an average of 5 kg of feed/day in week 1 and 8 kg/day in week 2 (Anil et al., 2006). Characterization of feed intake changes in lactation as major (a decline in intake of 1.6 kg for 2 d or more) or minor (1.6 kg for 1 d) showed that the major decline delayed wean to conception, increased anestrus and increased culling, especially when occurring in weeks 1 or 2 (Koketsu et al., 1996). One study also reported effects of both sow genotype and the effect of nursing litter size (8, 11 or 14 pigs) on sow feed intake, litter weight at weaning, backfat loss, and wean to service interval. As a result, sows with lower BW loss in first lactation had a larger 2nd litter size and a reduced wean to service interval (Eissen et al., 2003). Pig removal and transfer in late lactation is used to help improve overall pig weaning weights. Early and split weaning (Knox and Probst-Miller, 2004) may cause failures in some sows as a result of intermittent suckling causing cystic ovaries in 10-20% of sows (Gerritsen et al., 2014). These practices, while used on a small proportion of sows, can cause problems and lead to extended periods of non-productive days.

Gilts most notably, and sows can often be culled after their first low litter size. Litter size is known to be influenced by inseminator technique (Flowers, 1996) and is likely a result of estrus detection skills, AI timing decisions, and insemination technique. Research has shown that excessive leakage at time of AI can reduce fertility, especially when sperm numbers are low, semen fertility is compromised by age, or AI timing is too far from ovulation. To minimize the risk of culling for low litter size due to skill of the technician, training for AI protocols should be established and reviewed periodically based on record analysis. Semen fertility and the effect of boar can also impact litter size. Low litter size has been noted when semen quality declines and can be attributed to low motility and

sperm abnormalities. Lowered sperm fertility also occurs as semen ages in storage, and should not be used beyond a certain number of days for each class of extender. To minimize the impact of semen fertility, medium and long-term extenders are used to increase shelf-life, and pooled semen with 3 or more boar ejaculates in a mix, are used to minimize the risk of any single sire or ejaculate reducing litter size.

CONCLUSIONS

The causes of reduced longevity reside in the area of involuntary culling for reproductive failure and poor litter performance. While the causes for each of these failures can be single and in some cases multi-factorial, making changes for increased sow retention past parity 3 will require more detailed information to make advances. Information on the female, her history, recent events and observations from different stages of production would be important for helping troubleshoot problems and minimize problems in the future. While it may not be possible to correct ongoing fertility problems in certain females, it may be most effective to try and prevent similar types of problems in subsequent groups of sows identified for risk of failure. Knowing the risk factors associated with the specific types of failures on farms could help identify factors that can be controlled to reduce the incidence of these types of failures in the future. Treating each case of failure as unique will allow for a thorough accounting for history, and will provide the greatest chance for identifying contributing factors and eliminating these risks.

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OPTIMIZING LOOSE HOUSING

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FOREWORD

A big part of the world is going to group housing for sows.

Code of Practice in Canada:

For existing farms that do not undergo renovation, stall housing is permitted until July 1, 2024.

“As of July 1, 2024, mated gilts and sows must be housed in groups; or in individual pens; or in stalls, if they are provided with the opportunity to turn around or exercise periodically, or other means that allow greater freedom of movement.”

In most of European countries, group housing has been mandatory since 2013. Since the legislation is part of a European directive, member states may adopt stricter-than-national provisions. This can lead to additions or minor deviations. The majority of member states, however, have adopted the requirements unchanged.

The directive distinguishes between sows that have farrowed (sows) or have not yet farrowed (gilts). The area requirements for gilts is about 25% lower than for farrowed sows. The Netherlands has levelled up to the highest space requirement for all sows and already requires group housing from four days after insemination. Austria adopted, under serious societal pressure, higher requirements, in which sows from ten days after weaning have to be group housed. That is more or less comparable to the Dutch demand. The Austrians further require loose farrowing systems; which is required after renovation or at least beginning 2032. Already now in Sweden, farrowing sows must be free to walk around in the pens. Also in Sweden a completely slatted floor is forbidden, and a straw layer is demanded for all categories of pigs.

INTRODUCTION

Loose housing can be done in different ways, as we have:

- Crates with free access
- Small groups of 6-8 sows
- Larger groups of 20-30 sows with long trough
- Electronic Sow Feeding (ESF)

I would like to share with you some of the aspects that are helping to optimize loose housing systems. A great deal of the information is coming from ESF systems because I have built up most of my expertise in this field over the decades.

I will be discussing some of the layouts and why some are more practical than others. I will also discuss automatic heat detection in the optimum layout, as well as the introduction of gilts.

During the years we have learned that it is important to do more than think only about sows. In particular, the gilt needs to learn about group housing. This includes teaching her social behaviour and other skills for behaving as a sow in a group. This will support her future wellbeing. I also will share information about the importance of the condition of the sows in optimizing the production in loose housing systems – especially because we are still increasing the litter sizes.

LAYOUTS

Wageningen UR Livestock Research did a survey (see report 283) on different farms in 2008. They visited 70 farms with group housing. These farms were selected on the basis of the following criteria:

- Sows and gilts were accommodated in the group within 4 days post-insemination.
- Group housing applied from December 2004 or earlier.
- No changes were made in the group housing system during 2006 and 2007.

They found negative/unfavourable relationships. One of them is passage around the feeding station (feeding station without straw). It is unfavourable if sows that have eaten can immediately go to the entrance of the feeding station again. Farms in which this passage is possible experience more skin lesions in sows.

In the following sketch (Figure 1), this is made visible. You see on the left a layout that is not as favourable. The sows can go immediately back to entrance of the feeding stations. On the right you see a more favourable layout.

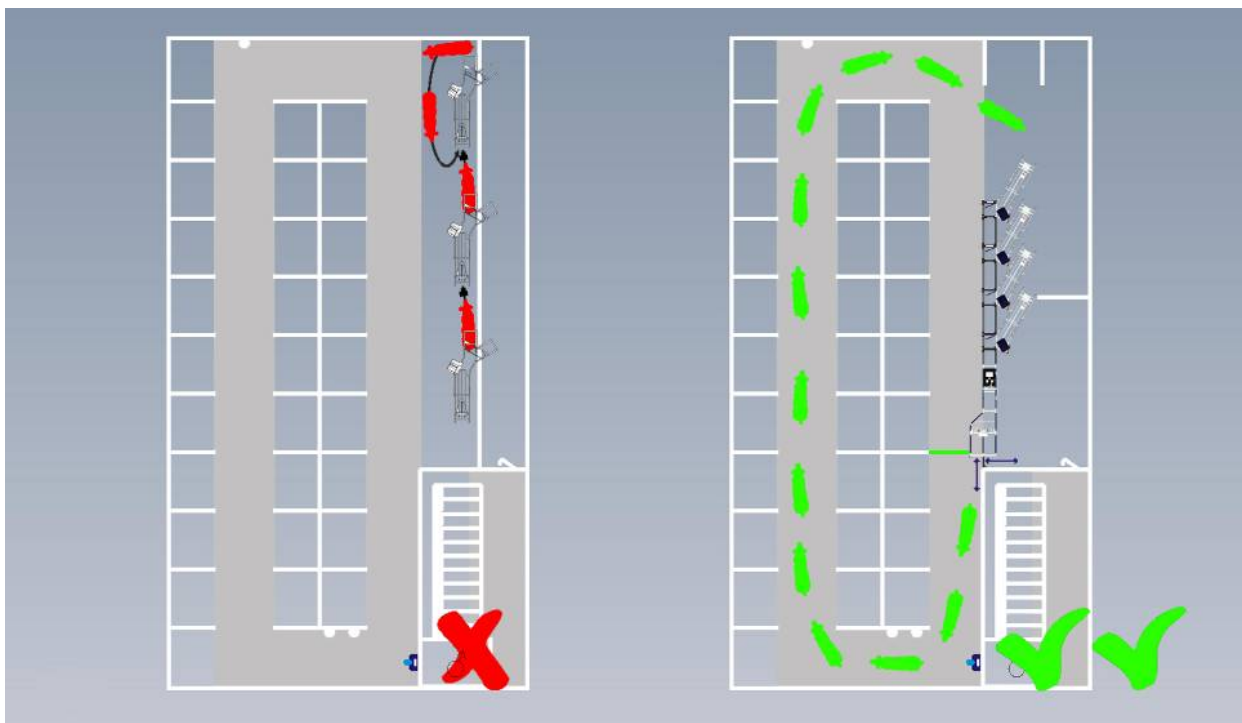


Figure 1. Two schematic layouts.

Figure 2 shows an easy way for checking the sows. You will not miss any sows if you walk in the opposite direction of the sow flow.

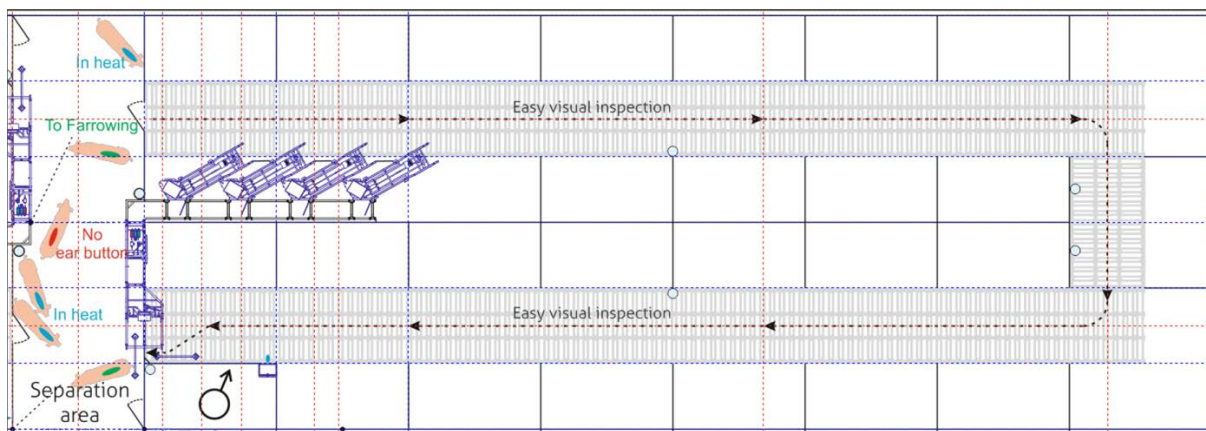


Figure 2. Practical layout with a separation area, where spray marked sows in 3 colours can be seen.

AUTOMATIC HEAT DETECTION

When using the one-way-routing layout, the heat detection works much better because sows are passing the boar pen at least one time a day. This gives an advantage in that sows can be separated automatically in an early stage. This results in:

- Labour savings. The automatic heat detection (Figure 3) works 24/7.
- More rest/quietness in the group housing. For example, you will have no mounting in the group because sows are detected and separated out of the group housing before they are in standing heat.
- More efficiency. In the group they are fed automatically with the ESF. When they are moved to stalls, you have to feed them by hand and personnel has to check for heats versus in the group where this happens automatically. (no scanning at 35 days needed!)

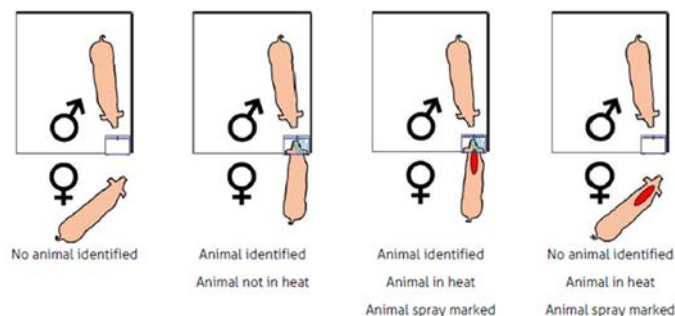


Figure 3. Heat detection explanation.

SEPARATION AREA IN ONE CENTRAL PLACE

This makes for a very short and efficient walking route for workers and sows that need to be transported to another area. It also has some add-on advantages:

- Easy calibration of the feed dosing because all feed stations are next to each other.
- Sows that lose their RFID tags are automatically taken out of the group.

PANELS IN THE LAYING AREA.

It is preferable that the height for panels in the laying area is between 60 cm and 70 cm high within the group. Between the different groups, the preferable height is 1 meter.

When internal panels are lower, it gives a better overview for the herdsman (Figure 4). The impression is also that the sows are less afraid. They see who/what is coming, which again gives more rest in the group.



Figure 4. Picture with panels in the laying area.

GILT DEVELOPMENT

We normally talk about group housing of sows. During the years, we have come to know that there is more than only thinking about sows. We also have to teach the gilt about the group housing. This means teaching her social behaviour and more skills that will be necessary for her wellbeing later as a sow.

Pre-training and adaptation to the feed system the gilts will have as a sows is important. In the case of a feed station, spend at least one week training a gilt on ESF. This ESF station should be smaller and shorter than the sow feeding station (Figure 5).

The lower picture shows a pre-training room for teaching gilts to go from one pen to the other pen. On one side is water, the other side feed. The upper is a teaching feeding station system.

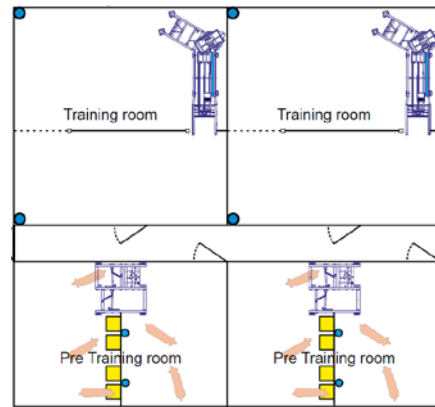


Figure 5. Pre-training and training for gilts.

Today we see the first GDU using a Sorting system. Normally these are used for fattening pigs. A sorting system with identification can give more detailed data to be used for selection of the gilts. We can also see that they are trained with more social skills.

THE IMPORTANCE OF THE SOW'S CONDITION IN OPTIMUM LOOSE HOUSING

DeHeus feed company in the Netherlands did a research study on 5,000 sows located on different farms. They measured the back fat at farrowing and looking at the productivity of the sows (Figures 6 and 7).

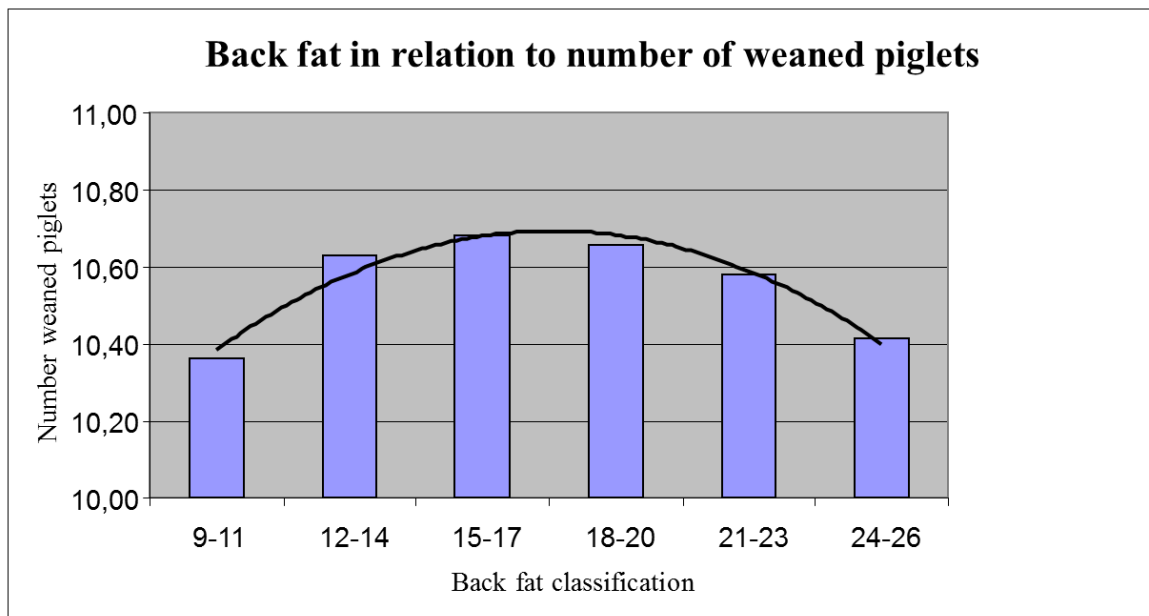


Figure 6. Back fat (in mm) in relation to number of weaned piglets at farrowing (5,000 sows)

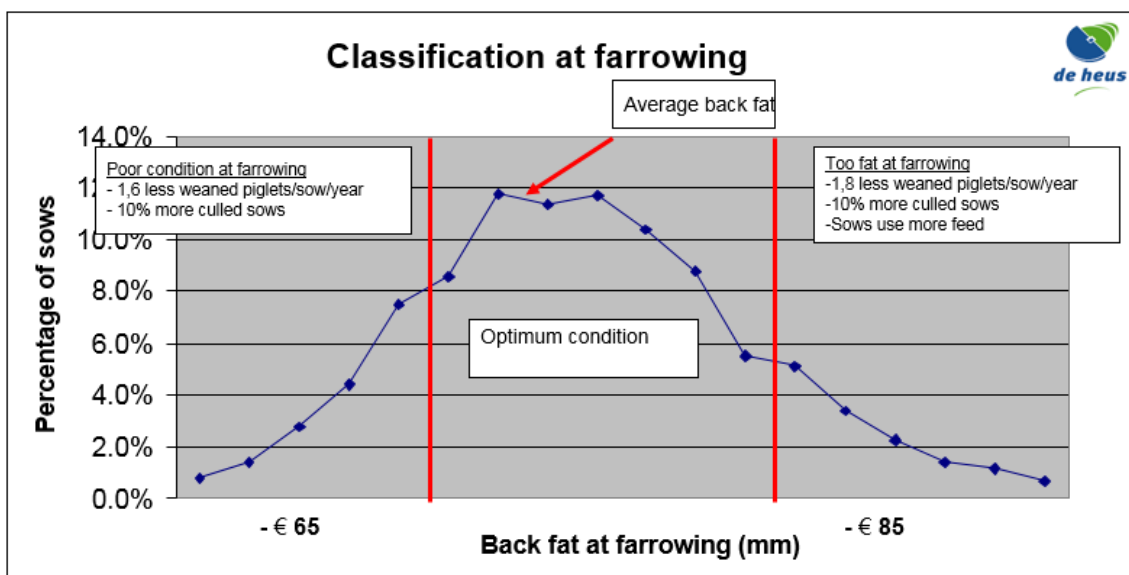


Figure 7. Classification of back fat at farrowing and the cost for a thin or fat sow.

Sows who are in poor to good condition are costing respectively 65 euro (95 Canadian dollar) and 85 euro (124 Canadian dollar) a year (conversion rate 18 march 2016).

When feeding the sows individually, they can be kept in optimum condition, which is also the experience we have had over the years with ESF.

Sow productivity with individual feeding has a positive effect on number of weaned piglets per year (Figure 8).

Figures 2010	Number of sows	Introduction sows straight after insemination in group housing	live borne piglets/sow/year	weaned piglets/sow/year
875 Farms Agrovision	368 average sows		31,6	27,5
Farm 1	500	Dynamic group	33,5	30,1
Farm 2	2100	Static	31,9	28,5
Farm 3	1011	Static	35,6	31,2
Farm 4*	1967	Static	30,36	26,3
Farm 5	228	Dynamic group	34	28,44
Farm 6*	284	Dynamic group	33,6	29,4
Farm 7	345	Dynamic group	35,8	31,1
Farm 8	860	Dynamic group	35,2	31,2
Farm 9	420	Dynamic group	32,8	29,1
Farm 10	437	Dynamic group	34,5	30,7
Farm 11	724	Static	32,5	28,1
Farm 12**	700	4 weeks Static	32,1	28,3
Farm 13	655	Dynamic group	34,6	27,6
Average of 13 farms	787		33,57	29,23
Compared with 875 farms			1,97	1,73
* Illness in herd **Result from 06-10 till 05-11 Nedap: Arno van Brandenburg				

Figure 8. Number of live borne and weaned piglets on 13 farms with ESF compared with average in the Netherlands 2010.

OPTIMIZE FEEDING IN FAROWING PEN TO KEEP UP GOOD CONDITION

Another challenge is that the sows should not lose too much weight during lactation, which is important again when they go in group housing after insemination.

Feeding them optimally in lactation with an automated feed curve can be a way to prevent too much weight loss. It also seems that 4 (or more) times per day feeding stimulates the feed intake and, with that, the milk production of the sow. The sows stay in better condition to keep the interval between weaning and insemination as short as possible (Thaker, 2005).

They established that as weight loss increases, wean-to-estrus intervals lengthen. From a 5-day interval for a weight loss of 5% or less, it reaches 10 – nearly 11 – days when weight loss reached 20% and more.

Below is an example of how we stimulate the feed intake at lactation, by feeding them more times a day (Figure 9).

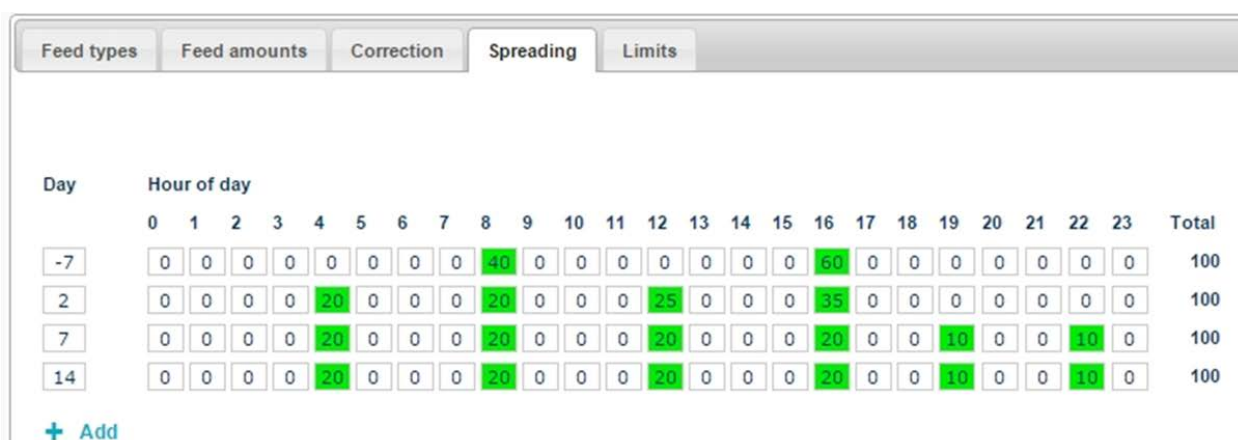


Figure 9. Example of spreading the feed over the day before and after farrowing.

CONCLUSIONS

To optimize a loose housing system with ESF, one-way routing for the sows is preferable. Panel division between laying areas should not be too high. It is important to teach gilts social skills in early stages so they become well socialized sows in any group housing system. To keep sows in good condition during pregnancy, an individual feeding system can optimize productivity. This is also important during lactation. This will become a greater challenge if sow productivity increases.

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THE MODERN SOW: TOP PRODUCTION ISSUES

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ABSTRACT

The North American pork industry has substantially increased the number of piglets born per litter. Improvement in litter size was achieved through better management and implementation of effective genetic selection programs for litter size. However, the increase in number of piglets born per litter is associated with more piglets with low birth weight, increased preweaning mortality of piglets, and a greater demand placed on the sow to produce more milk. There are people who have stated concerns about the welfare of the animals. The health and welfare concerns can be minimized by using proper management procedures and excellent caretakers.

Some of the management aspects that can help increase preweaning survival include: understanding the complex interaction between the sow, piglet, environment and caretaker; managing to correct for number of non-functional mammary glands and nipples; effective management of colostrum when sows have a large number of piglets; effective use of cross-fostering procedures; managing lactation feed intake for genetically lean sows with large litters; utilization of a detailed procedure for training and supervising new employee.

INTRODUCTION

A few years ago the British Pig Executive group (BPEX; UK pig levy payers) initiated a program called Two Tonne Sow (2TS). The purpose of the program was to help English pork producers be competitive in Europe by 2012. The program was designed to help the pork industry achieve an average of 2,000 kg of pig carcass per inventoried sow per year. Today, there are individuals in North America wanting their sows to be categorized as 3TS or 4TS. It needs to be clearly indicated how these categories are defined, such as: kg of carcass vs. kg of live weight; productive sow vs. inventoried sow; and metric ton (2,204 lbs.) vs. short ton (2,000 lbs.). The accomplishment of these types of goals place a significant amount of pressure on: (1) the gilts and sows to perform at a high level of reproductive performance, and (2) the caretakers to do an excellent job in all phases of production. As indicated in Figure 1, it takes a “Team of Skilled Workers” to produce a high volume of pork per sow per year. Effective caretakers are people who take care of pigs with compassion, dedication and adequate knowledge about how to manage all the requirements of the pigs (feed, water, housing, environment, pig handling procedures, insemination procedures, health management, etc.). The purpose of this paper is to focus on a few aspects related to sow productivity that has not been presented during the last few years.

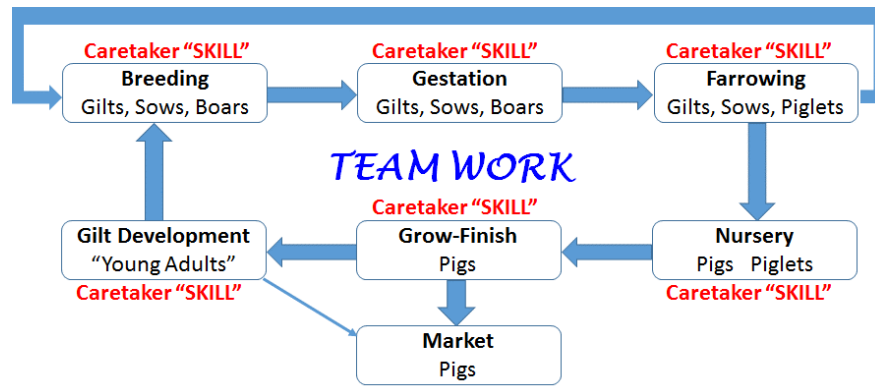


Figure 1. Excellent productivity of a pork production enterprise requires teamwork by skilled caretakers in all aspects of producing pork.

MODERN SOW CHARACTERISTICS

The requirements of today's sow are: (1) obtain puberty at a young age, (2) farrow a large number of live born piglets per litter, (3) produce an adequate (large) volume of milk during the entire lactation period to sustain rapid growth of piglets, (4) wean a large number of piglets per litter, (5) lose a minimum amount of backfat/body fat during lactation, (6) recycle within 7 days after weaning, (7) have an increase in number of piglets farrowed per litter from 1st litter to the 4th litter, and (8) have a minimum lifetime productivity of 60+ weaned piglets by 6th litter farrowed [high reproductive efficiency per litter and high longevity] (Figure 2). With regard for reproductive performance across parities in Figure 2, sows having 15 or more piglets born alive in their first litter had 0.5 to 1.8 more ($P < 0.05$) piglets born alive in any subsequent parity compared to parity 1 sows having 8 to 11 or 12 to 14 piglets born alive per litter. This data supports the position that gilts farrowing a large litter will have high individual litters and lifetime performance.

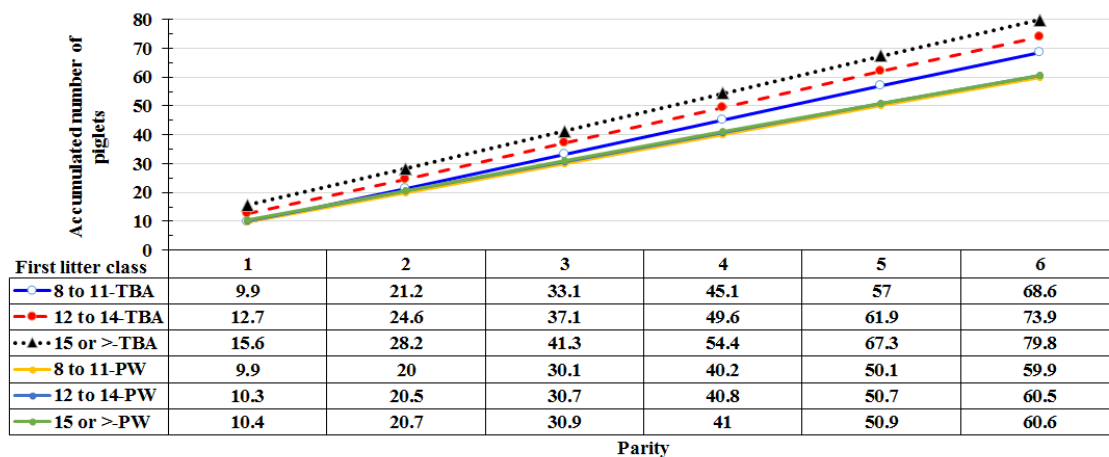


Figure 2. Accumulated number of piglets born alive (TBA) and number of piglets weaned (PW) when sows are categorized by number of piglets born alive per litter in parity 1 (adapted from Iida et al., 2015).

The desire by the pork industry to improve production efficiency has resulted in a steady increase in the total number of piglets born per litter (Figure 3) and number of piglets born alive per litter (Figure 4). Figure 5 indicates that preweaning mortality is quite variable among farms using the PigCHAMP records program.

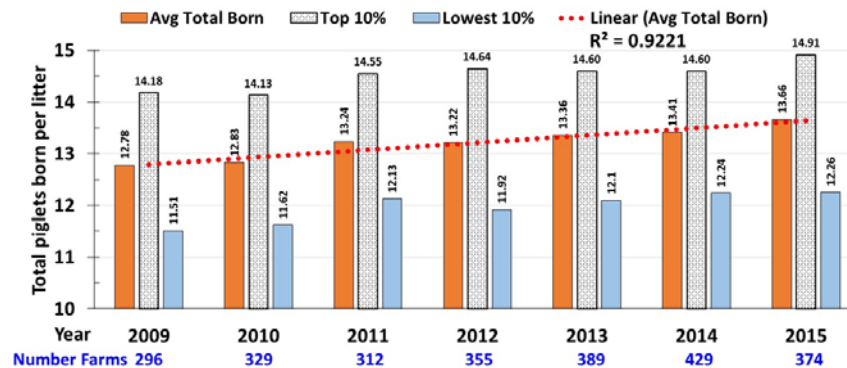


Figure 3. Linear increase in total number of piglets born per litter in United States sow herds from 2009 to 2015 (PigCHAMP Benchmarking, 2009-2015).

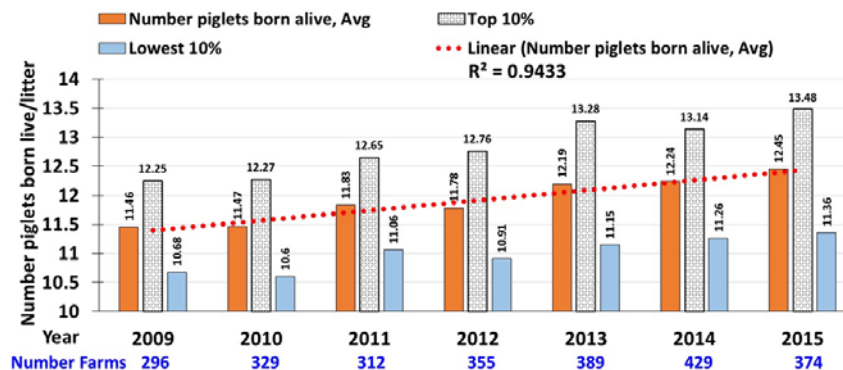


Figure 4. Linear increase in number of piglets born alive per litter in United States sow herds from 2009 to 2015 (PigCHAMP Benchmarking, 2009-2015).

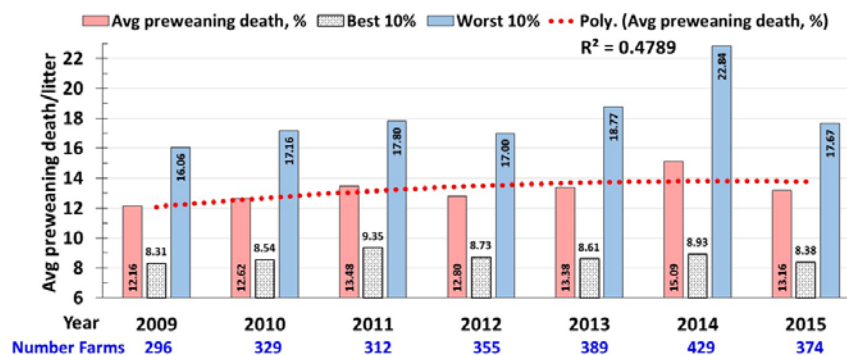


Figure 5. Preweaning death loss per litter in United States sow herds from 2009 to 2015 (PigCHAMP Benchmarking, 2009-2015).

The increase in number of piglets born per litter is associated with more piglets with low birth weight and increased piglet mortality. Based on an extensive review of the scientific literature, Purnier et al. (2010) stated that high physiological demands of modern sows to produce more pigs are likely to induce health and welfare problems. In addition, there have been two very extensive literature reviews concerning the welfare of piglets and sows due to biological and management factors associated with large litter size in pigs (Baxter et al., 2013; Rutherford et al., 2013). Baxter et al. (2013) stated: “*Societal acceptance of pig production may be negatively affected if efforts are not made to mitigate the negative welfare outcomes of increasing litter size.*” The intensity and frequency of health and welfare problems can be minimized by using appropriate diets and rationing, good housing designs, controlling environments, correct genetic composition of sows for maternal behaviour and ability to produce colostrum and milk, and adequately trained and dedicated caretakers.

PREWEANING MORTALITY

One of the most important factors in pig production is litter size at weaning. The loss of live born piglets from birth to weaning is a major problem on most farms. Preweaning mortality is defined as the number of piglets born alive that died before weaning. Mortality of piglets raises welfare and economic concerns for farrowing systems with or without farrowing crates and both indoor and outdoor pork production enterprises. Although numerous factors influence preweaning mortality, several publications have reported preweaning mortality values ranging from 5% to 25% (Alonso-Spilsbury et al., 2007; Anderson et al., 2007; Strange et al., 2013; Hellbrugge et al., 2008).

Survival indicators

The survival of piglets involves a complex interaction between the sow, piglets, environment and caretaker. Because piglets are born without immune protection and body fat for energy, they have to quickly acquire colostrum from their mother. Piglets are at risk when trying to acquire colostrum due to: (1) being crushed by the sow, (2) becoming hypothermic while wrongfully searching for the udder along the pen partitions, and (3) starving because they lack strength and vigour to establish “ownership” of a functional mammary gland and nipple. A study in Scotland used a time-lapse video cassette recorder to continuously film 10 sows farrowing naturally in standard farrowing crates and 135 piglets from 2 days pre-farrowing until 24 h post-farrowing (Baxter et al., 2008). Compared to subsequently dying piglets, surviving piglets were characterized as: (1) having a greater birth weight, (2) born in a smaller litter, (3) born earlier in the birth order, (4) quicker to arrive at the udder, (5) quicker to locate a functional teat, and (6) quicker to suckle and consume colostrum (Table 1).

Thermoregulation of body temperature is closely related to birth weight. Thus, smaller piglets have a greater risk from hypothermia because heat loss per unit of body weight is inversely related to body size. The rectal temperature of piglets that died was significantly lower immediately after birth and at 1, 2, 3 and 24 hours after birth. Although the majority of piglets had their birth rectal temperatures taken within 5 minutes of being born, rectal temperature was already significantly different between those piglets surviving and those dying.

Table 1. Postnatal survival indicators comparing surviving piglets with those dying during the neonatal period before weaning (adapted from Baxter et al., 2008).

Item	Piglets surviving ¹	n	Piglets dying ¹	n	P-value
Litter size	14 ± 0.32	113	18 ± 0.31	13	<0.001
Birth order	7 ± 0.40	113	10 ± 1.54	13	0.018
Birth weight, g	1485 ± 30.3	113	1176 ± 79.4	13	<0.001
Vitality score ²	2.28 ± 0.06	113	1.77 ± 0.20	13	0.017
Time from birth to arriving at the udder, min.	19 ± 1.21	113	26 ± 4.97	13	0.107
Time from birth to locating a teat, min.	22 ± 1.24	108	34 ± 6.52	13	0.025
Time from birth to starting to suckle, min.	29 ± 1.67	102	53 ± 8.32	13	<0.001
Rectal temperature					
At birth	37.70 ± 0.13	103	36.47 ± 0.61	11	0.012
1 hour after birth	37.94 ± 0.10	102	36.70 ± 0.48	13	0.002
2 hours after birth	38.02 ± 0.07	83	37.54 ± 0.33	11	0.047
3 hours after birth	38.02 ± 0.06	106	37.53 ± 0.13	13	0.010
24 hours after birth	38.29 ± 0.07	113	37.58 ± 0.26	12	0.004

¹Mean ± S.E.

²Vitality score: 0 = No movement, no breathing after 15 s; 1 = No movement after 15 s, piglet is breathing or attempting to breathe (coughing, spluttering, clearing its lungs); 2 = Piglet shows some movement within 15 s, breathing or attempting to breathe; 3 = Good movement, good breathing, piglet attempts to stand within 15 s.

Genetics

It is well documented that a large number of piglets born per litter will increase the number of stillborn piglets and preweaning mortality. Arango et al. (2006) documented that 53% of all live piglets dying before weaning occurred by the fifth day after birth. Selecting sow lines for total number of piglets alive at five days after birth [TNB – number stillborn – dead pigs up to day 5 after farrowing] has increased total number of piglets born per litter, reduced mortality rate at time of farrowing [(TNB – Litter size at day 5) / TNB], and increased number of piglets alive per litter at five days after farrowing (Figure 6; Nielsen et al., 2013). Animal caretakers who work in the farrowing facility have to be well trained and dedicated to keeping a large number of piglets per litter alive during the first 3 days after birth, especially day 1.

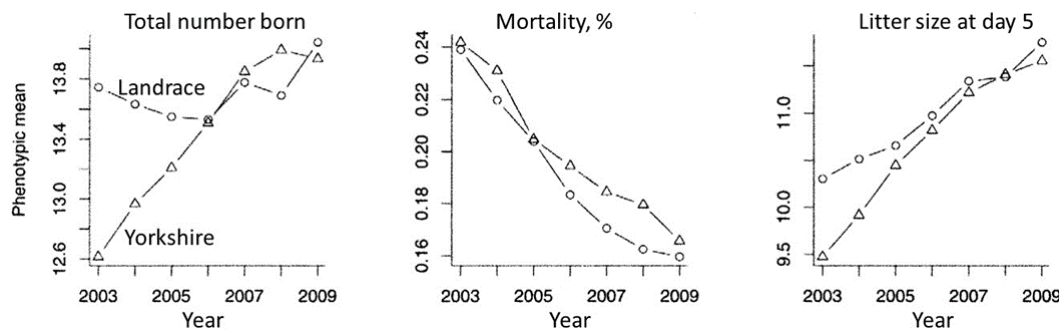


Figure 6. Averages by sow year of birth for total number of piglets born, mortality of piglets, and litter size at day 5 after farrowing in the first parity (gilt results) of Landrace and Yorkshire populations (adapted from Nielsen et al., 2013).

Birth weight variation and survival

It is well known that piglet birth weight has a significant amount of variation within a herd and within a litter of pigs (Ferrari et al., 2014; Quesnel et al., 2008; Quiniou et al., 2002). In Table 2 the average number of total piglets born (stillborn and live born) per litter was 12.5 ± 3.2 (range: 2 to 22 piglets).

Table 2. Effect of birth weight on piglet survival at time of weaning (adapted from Quiniou et al., 2002)

Birth weight, kg	Total born	Born alive	Stillborn	Alive after fostering ^a	Percentage of piglets surviving at ^b			
					Day 1	Day 7	Day 14	Weaning ^c
< 0.61	199	152	47 (30.9) ^d	102	36	16	16	15
0.61-0.80	435	389	46 (10.5)	343	71	51	48	48
0.81-1.0	949	883	66 (6.9)	815	85	75	73	71
1.01-1.2	1643	1549	94 (5.7)	1468	91	87	86	85
1.21-1.4	2412	2309	103 (4.3)	2213	94	91	90	89
1.41-1.6	2622	2525	97 (3.7)	2470	96	94	93	92
1.61-1.8	2069	2006	63 (3.0)	1979	98	96	95	95
1.81-2.0	1130	1116	14 (1.2)	1097	97	96	95	95
2.01-2.2	418	412	6 (1.4)	410	99	99	98	98
2.21-2.4	127	126	1 (0.01)	126	99	98	96	96
>2.4	38	37	1 (2.6)	37	100	100	97	97

^aPiglets born alive minus piglets that died after birth because of crushing, savaging by sow or euthanasia. Cross-fostering was accomplished within 48 hours after farrowing.

^bExpressed as a percentage of number alive after cross-fostering.

^cAverage weaning age was 27 days.

^dNumber in parenthesis is percentage stillborn of total born

When birth weight of piglets was 0.81 kg or greater, the percentage of stillborn piglets was less than 7% of the total born and the percentage of piglets alive at weaning ranged from 71% to 97%. When birth weight of piglets was less than 0.61 kg, the stillborn rate was 30.9% and only 15% of the piglets were alive at weaning. When piglets weighed 0.61 to 0.80 kg at birth, 48% were alive at weaning. More recent data (July to October 2012) from a farm with 4,300 sows was analyzed to study the influence of birth weight on piglet mortality between 24 hours after birth and 42 days of age (Table 3). Among piglets weighing ≤ 1.20 kg at birth ($n = 151$ piglets), the mortality rate was 13.9%. Among piglets weighing greater than 1.20 kg at birth ($n = 449$ piglets), the mortality rate was 5.1%.

Number of functional mammary glands and nipples

Scientific publications have indicated that udder problems (low or no milk production, mastitis, udder abscess) account for < 1% to 18% of the reasons for culling sows (Engblom et al., 2007, 2008; Hadas et al., 2015; Segura-Correa et al., 2011; Zhao et al., 2015). Although sows can have udder problems at any parity, the most frequent culling due to udder problems occurred at parities 4 to 6. Most likely, the culling rate for udder problems is low because sows that have one or two low producing mammary glands or nonfunctional nipple(s) are not culled. When sows are moved into the farrowing facility, the number of non-functional mammary glands and nipples on each sow in the farrowing group should be counted and recorded. This process helps the farrowing house worker to

quickly locate a functional nipple/gland when a current sow is farrowing more piglets than she can nurse.

Table 3. Mortality of piglets that died between 24 hours after birth and 42 days of age according to intervals of birth weight (adapted from Ferrari et al., 2014).

Birth weight, kg	Total pigs	Number pigs died	% died ¹	Birth weight, kg	Total pigs	Number pigs died	% died ¹
1.10-1.15	82	10	12.2	>1.35-1.40	78	1	1.3
>1.15-1.20	69	11	15.9	>1.40-1.45	66	4	6.0
>1.20-1.25	71	6	8.4	>1.45-1.50	59	2	3.4
>1.25-1.30	78	7	9.0	>1.50	38	0	0
>1.30-1.35	59	3	5.0	Total	600	44	7.3

¹Percentage of piglets that died between 24 hours after birth and 42 days of age.

What is the nursing capacity of a group of sows farrowing? If 30% of 50 sows in a farrowing group have one non-functional gland/nipple, the reduction in nursing capacity is 15 piglets. On a weekly basis, this reduction in nursing capacity would translate into 780 pigs per year. With a large number of piglets born alive per litter, the number of functional mammary glands is critical for piglet survival because each piglet has to have their own nipple.

Research results have demonstrated that suckled teats in the first lactation produce more milk and have a greater development in the second lactation than non-suckled teats (Farmer et al., 2012). It is also known that the piglet's body weight and vitality influences the piglet's ability to extract colostrum from the mammary gland. The composition of colostrum changes very rapidly towards that of milk during the first 24 to 36 hours postpartum. Suckling by piglets induces and maintains the second stage of lactation that produces an abundant supply of milk (Theil et al., 2006); whereas, non-suckling causes the mammary gland to undergo involution. These aspects would suggest that a gilt should have all of her mammary glands/nipples nursed by piglets with adequate body weight and vitality. However, first-litter sows have lower ($P < 0.001$) colostral IgG concentration when compared to second parity or more sows (Cabrera et al., 2012). In addition, the mammary gland size (tissue and DNA) of first-litter sows is smaller than in multiparous sows (Nielsen et al., 2001); thus, resulting in a reduction of up to 21% in milk production compared to parity-four sows (Beyer et al., 2007).

Colostrum management

The anatomical structure of the pig placenta does not allow immunoglobulins to pass from the sow's blood system to the fetus (Rooke and Bland, 2002). Therefore the newborn piglet acquires immunoglobulins by drinking and ingesting colostrum. The birth of a large number of piglets per litter has increased the competition among litter-mates to acquire the needed amount of colostrum for survival. In addition, selection for a larger number of piglets per litter has reduced the average birth weight of piglets which has decreased their capacity to ingest colostrum (Foxcroft et al., 2009; Amdi et al., 2013). Although there are differences in colostrum availability between teats, it has been estimated that piglets need to consume greater than 250 grams of colostrum (Ferrari et al., 2014; Theil et al., 2014). Because the IgG concentration in colostrum rapidly decreases during the first 24 hours

after farrowing begins (Foisnet et al., 2010), farrowing house caretakers need to utilize procedures whereby all piglets have an opportunity to ingest 200 to 250 grams of colostrum (Table 4).

Table 4. Effect of colostrum intake on mortality of piglets that died between 24 hours after birth and 42 days of age (adapted from Ferrari et al., 2014).

Colostrum intake, g	Total pigs	Number pigs died	% died ¹	Colostrum intake, g	Total pigs	Number pigs died	% died ¹
0-100	33	9	27.3	>300-350	94	2	2.1
>100-150	45	9	20.0	>350-400	87	4	4.6
>150-200	46	6	13.0	>400-450	50	1	2.0
>200-250	83	6	7.2	>450	<u>35</u>	<u>1</u>	2.9
>250-300	127	6	4.7	Total	600	44	7.3

¹Percentage of piglets that died between 24 hours after birth and 42 days of age.

It is impossible for all newborn piglets to suckle at the same time when there are 15 to 18 piglets in the litter. However, colostrum can be shared by piglets soon after birth. If caretakers are closely monitoring the farrowing process, the largest 7 to 9 piglets can be marked and placed in a warm area for 2 hours while the smaller piglets suckle.

Cross-fostering

Selection for increased number of piglets born alive per litter has increased a need for cross-fostering of piglets. It is important to remember that all piglets need to consume an adequate volume of colostrum from their mother before being moved to another lactating sow. Consuming their mother's colostrum is important because the piglets may have to be moved to a sow that farrowed 1 or 2 days before receiving transferred piglets. The smaller and weaker piglets should be the first group of concern. If the caretaker thinks that the weak piglets should be left with their mother then move the larger and stronger piglets. Small piglets should only be moved to new litters that have a similar birth weight. When sows farrow overnight, piglets may be 8 or more hours old before transfer can take place. Suckling behaviour of piglets should be another criterion for fostering. Piglets which cannot establish "ownership" of teats are the first candidates for fostering. However, if a small piglet in a large litter has a stable suckling position, it is a good idea to leave them with their litter-mates. Cross-fostering is more challenging when piglets are transferred into large litters. Research using Large White sows in Italy has documented that the probability of survival decreased for piglets joining large litters of 12 to 14 piglets or very large litters of more than 14 piglets in comparison with litters of 6 to 11 piglets (Cecchinato et al., 2008). Regardless of the cross-fostering procedure, a key objective is to enable all piglets to have access to a functional teat; thus, they have a realistic opportunity to survive.

BIRTH WEIGHT EFFECT ON SUBSEQUENT GROWTH AND MEAT QUALITY

During the lifetime of a sow, the number of piglets produced is important to the farm's profitability. The pork industry has successfully developed genetic lines of sows that farrow a large number of piglets per litter. The increase in piglets born per litter has

resulted in more piglets with low birth weights (0.8 to 1.0 kg) due to intrauterine growth retardation (Figure 7).

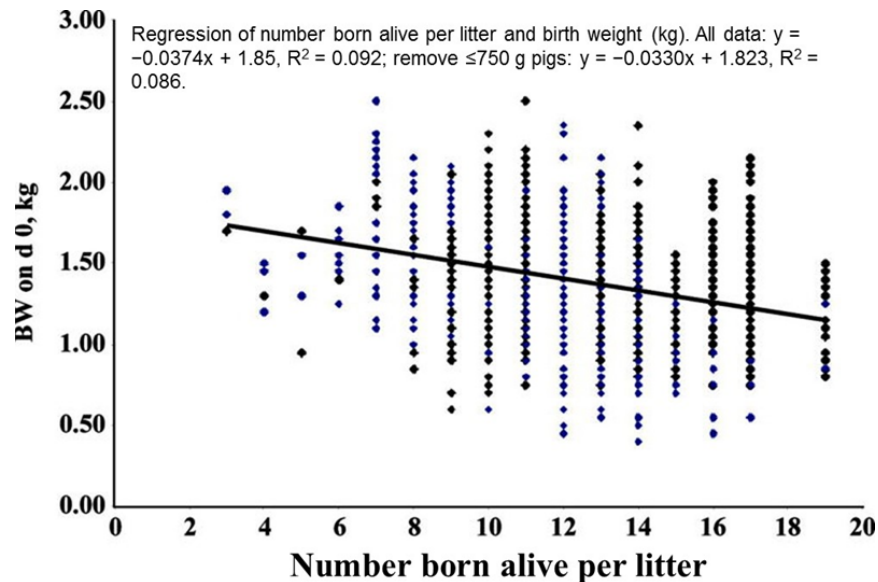


Figure 7. Effect of number of piglets born alive per litter on birth weight (adapted from Beaulieu et al., 2010).

Intrauterine growth retardation is defined as impaired growth and development of pig embryo/fetus or its organs during pregnancy. Insufficient uterine capacity and inadequate maternal nutrition are two major factors that impair fetal growth. Before day 35 of gestation, pig embryos are somewhat uniformly distributed within the uterine horn. A large number of piglets in the uterus results in uterine crowding. Thus, some of the piglets do not have sufficient amount of uterine space for formation of the placenta that provides nutrients to the fetus. Uterine crowding affects fetal organ development and the number and type of muscle fibers. As depicted in Figure 8, muscle fiber development occurs after uterine crowding has made detrimental effects on fetal development and lifetime growth performance (Foxcroft et al., 2006). The problem of within-litter variation in birth weight is established by day 35 of gestation.

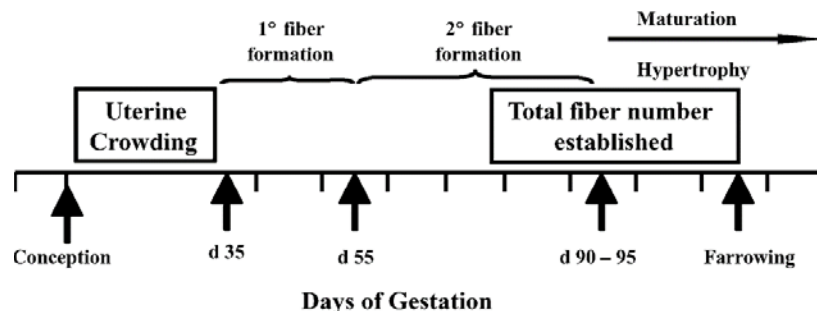


Figure 8. Schematic showing when uterine crowding occurs and muscle fibers develop in the pig (Foxcroft et al., 2006).

Table 5 indicates the effect of birth weight on growth performance, carcass quality and eating quality of pork. The conclusions from three of the studies indicated that low birth weight piglets are slower growing from weaning to market and have carcass quality problems. The fourth study concluded that: (1) an increase in number of piglets born per litter reduces average birth weight, (2) lighter birth weight pigs have an increase in days to market, and (3) there were very limited effects of birth weight on carcass quality, physical properties of the meat, and overall eating quality of the pork.

Table 5. Effect of birth weight on growth, carcass quality and eating quality.

Birth weight categories¹	Basic findings of the research	Reference
LBiW: 0.80 to 1.0 kg HBiW: 1.75 to 2.05 kg	LBiW pigs: (1) had a reduced ADG during suckling and post-weaning period, (2) were 12 days older at harvest, (3) had reduced plasma IGF-1; (4) had a larger cross-sectional muscle fiber area, (5) had a larger number of muscle fibers	Gondret et al., 2005
LBiW: 0.94 kg MBiW: 1.39 kg HBiW: 1.80 kg	LBiW pigs: (1) grew slower, (2) exhibited higher percentage of internal organs, bones and skin, (3) percentage of muscle tissue was smaller, (4) contained less fat and protein, (5) significantly lower total number of muscle fibers during fetal growth, (6) lower carcass weight, meat percentage and loin muscle area, (7) higher internal fat percentage and drip loss, (8) higher percent of giant fibers in semitendinosus and longissimus (poor meat quality)	Rehfeldt and Kuhn, 2006
LBiW: 1.05 kg HBiW: 1.89 kg	LBiW pigs: (1) had a lower ADG during suckling, weaning to day 68, day 68 to harvest, (2) poorer gain:feed ratio, (3) were 12 days older at time of market, (4) had less lean meat content and fatter carcass, (5) larger fat cells, (6) larger myofiber cross-section and less myofiber cells, (7) less tender meat.	Gondret et al., 2006
LBiW: 0.75 to 1.20 kg 1.25 to 1.45 kg 1.50 to 1.70 kg HBiW: 1.75 to 2.50 kg	LBiW pigs: (1) had reduced body weight at weaning, 5 and 7 weeks postweaning, and first pull for harvest, (2) had significantly more intramuscular fat and desirable flavour, (3) other than increased days to market, there is no reason based on pig performance or pork quality to slow down the goal of the pork industry to increase sow productivity as a means to increase efficiency.	Beaulieu et al., 2010

¹LBiW = low piglet birth weight; HBiW = high piglet birth weight.

LACTATION FEED INTAKE

The farrowing of a large number of piglets per litter has increased the importance of adequate feeding of sows. Adequacy of a sow's nutritional regimen is critical to allow synthesis of sufficient milk for her litter and for maintaining reproductive potential after weaning. If dietary amino acid supply is not adequate, mobilization of significant amounts of maternal body protein occurs because of the high demand for amino acids during lactation. It is important that first-litter sows are fed properly because they are the future of the sow farm. Restricting feed allotment to first-litter sows has been reported to: (1) prolong the weaning-to-estrus interval, (2) have lower LH and FSH concentration, (3) lower LH pulse frequency and magnitude, (4) reduce growth of follicles during lactation period (5) increase loss of backfat and body fat, and (6) reduced embryonic survival.

Inadequate dietary amino acid intake in first-litter sows during early lactation results in lower LH secretion by day 10 after farrowing. If sows are fed a diet too low in protein, they are able to mobilize sufficient amino acids from body tissue during the initial 10 d of lactation to meet their metabolic demand for milk production. Because reproductive hormones are re-established during the first 7 to 10 days of lactation, farrowing house caretakers need to be careful when feeding the sows to not excessively limit the amount of feed provide to each lactating sow, especially first-litter sows. Extension swine specialists at Kansas State University recommend the feeding procedure indicated in Table 6 to maximize feed intake of lactating sows.

Table 6. Feeding strategy for genetically lean lactating sows from D0 (day of farrowing) to weaning (adapted from DeRouchey et al., 2007).

Feed in feeder when feeding	Farrowing to D2 lactation			Feed in feeder when feeding	Day 3 of lactation to weaning			
	Feeding Time				Feeding Time			
	AM	PM	Daily total		AM	Noon	PM	Daily total
Empty	1.8 kg	1.8 kg	3.6 kg	Empty	3.6 kg	3.6 kg	3.6 kg	10.8 kg
< 1.8 kg	0	0.9 kg	0.9 kg	< 1.8 kg	1.8 kg	1.8 kg	1.8 kg	5.4 kg
> 1.8 kg	0	0	0	> 1.8 kg	0	0	1.8 kg	1.8 kg

- **Morning Feeding** - All sows are fed 1 scoop (1.8 kg) if small amount of feed is left in the feeder, and 2 scoops if the feeder is empty.
- **Late Morning Feeding** - Feed a second time later in the morning or immediately after lunch using the same scheme (1 scoop if a small amount of feed remains and 2 scoops if the feeder is empty). If no feed has been consumed since morning, examine the sow to determine if she has a fever, retained pig, water drinker problem or other detectable reason for being off feed.
- **Afternoon/Evening Feeding** - A similar scheme is used for the afternoon/evening feeding, but use judgment if there is some feed left in the feeder. Sows that have had good appetites before this feeding, but still have greater than 0.9 kg of feed remaining should receive one scoop. Sows that have eaten all or that have 0.9 kg or less of previously provided feed should receive two scoops, and again if the feed has not been touched since the last feeding, investigate to see if there is a detectable reason for the sow being off feed. During the summer when sows tend to eat more feed in the evening, managers may want to consider adding an extra scoop in the afternoon feeding.
- The only deviation from this pattern is for day 0 to 2 after farrowing. During this time, the decision is to give zero or one scoop at each meal. Sows should not receive two scoops at a single feeding during this period.

Effect of ambient temperature

Although the temperatures in Ontario are not excessively hot (Figure 9) during the summer months, there can be days when the highest temperature reaches a level to reduce feed intake of lactating sows. When ambient temperature increases above the evaporative critical temperature (i.e., 22°C [71.6 F]; Quiniou and Noblet, 1999), the sow reduces voluntary feed intake to reduce heat production due to the thermal effect of digesting feed. This reduced voluntary feed intake has negative consequences on mobilization of body reserves, milk production, and future lifetime productivity of the sow. More daily allotment of feed should be provided for night consumption. If available, sows will consume 41% of their daily feed intake at night (Howdysshell, et. al., 2007).

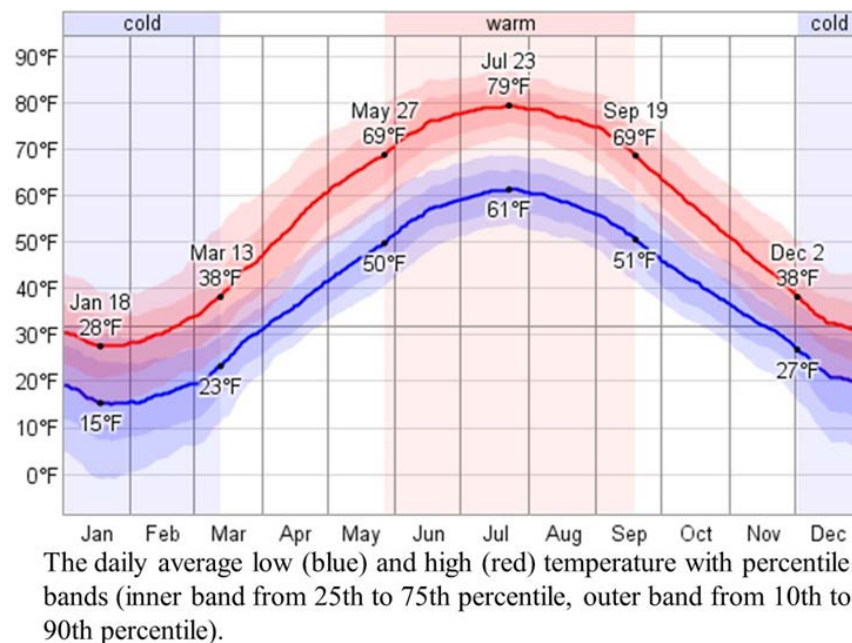


Figure 9. Daily average high and low temperature by month for London, Ontario (<https://weatherspark.com/averages/28428/London-Ontario-Canada>).

TRAINING AND SUPERVISION OF CARETAKERS

Adequate employee training is a weakness on many sow farms. Employees play an essential role in the success of a swine enterprise. No matter how carefully employees are recruited and selected, they will not come to their new job with all the necessary knowledge, skills and abilities required by the sow farm. Training is essential if employees are to reach their potential. Training should help the employee feel like they are creating better opportunities for themselves and at the same time helping the swine enterprise accomplish its goals. Numerous swine operations have a non-speaking English work-force; thus, do not assume the employee understands everything being spoken when they shake their head to indicate YES.

All new animal caretakers must be trained to accomplish the duties expected by the managers. The United States National Pork Board Pork Quality Assurance Plus program recommends a training technique called the PTSDR method. The training program is indicated in Table 7.

Table 7. The five steps for training employees with the PTSDR method¹.

1. Prepare	2. Tell	3. Show	4. Do	5. Review
<u>Step 1: Prepare Stage</u> The “Prepare” stage consists of the trainer preparing to train by focusing on the objectives and outcomes he or she wants to achieve within a training program. The prepare stage also consists of determining the time constraints needed for an individual to obtain a desired skill, as well as identifying any activities that should be implemented in the training program to enhance the knowledge and skills of individuals, then gathering the materials needed to carry out activities and the entire training program.				
<u>Step 2: Tell Stage</u> The “Tell” stage involves addressing the key points needed to obtain knowledge and skills. In this stage, the trainers share the information needed in order to complete the task. For example, when conducting a training session on animal handling, the trainer might discuss an animal handling brochure that covers specific information the trainee would need to know in order to properly handle or move pigs.				
<u>Step 3: Show Stage</u> The “Show” stage involves demonstrating how to complete a specific task. Continuing the example given above, this is the point at which the trainer would demonstrate how to properly handle or move pigs. This may take place in a barn with the animals.				
<u>Step 4: Do Stage</u> The “Do” stage enables the individuals to practice what they have been already told and what has been shown to them. In this fourth step, the trainee has the opportunity to practice properly moving and handling pigs, as they were told and then shown in the examples above.				
<u>Step 5: Review Stage</u> During the “Review” stage, the individual is evaluated on his or her performance of a desired task. After evaluation is completed, the individual is given feedback and recommendations for improvement.				

¹National Pork Board PQA Plus Education Handbook Version 2

SOW LIFETIME PRODUCTIVITY

During the last few years, the pork industry (breeding companies and commercial producers) has started to focus on sow lifetime productivity (SLP). The focus on SLP has increased due to economic importance of a high level of reproductive performance, gilt development cost and current level of culling sows. The high level of culling has been associated with welfare issues because of pain (feet and leg problems, downer sows, etc.) and emaciated sows (extremely thin). The majority of scientific studies on sow longevity have been conducted with purebred sows; however, purebred sows in nucleus and multiplier herds are generally replaced early in life with younger sows that possess better breeding values to maximize genetic improvement. Because numerous factors can influence SLP, each farm should evaluate what the SLP value is for their farm.

CONCLUSIONS

Enhancing reproductive performance of the sow herd requires dedicated employees who have a good understanding of the multifactorial aspects that influence the problem. The pork industry has done a good job of developing sows to farrow a large number of piglets per litter. However, an increase in litter size born alive is associated with increased piglet mortality and a greater demand on the sow to produce a large volume of milk to support the piglets. The required husbandry skills of caretakers has increased because numerous sows are now farrowing more piglets than they can nurse; thus, colostrum management and cross-fostering skills are needed. Because large litters require a large volume of milk per day, the management of lactation feed allotment is critical. Excellent management needs to be used every day whereby all piglets and sows are provided appropriate welfare conditions.

PAY CLOSE ATTENTION TO THE DETAILS!

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Day 1: Sows – Workshop Sessions

MANAGING THE HEALTH STATUS OF THE SOW

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INTRODUCTION

Infectious diseases continue to cause considerable challenges for swine health and welfare. At the population level, they contribute to reduced average output and increase in variability. As such, they have a negative impact on profitability and complicate pig flow at the farm and production system levels. Severe manifestations of infectious diseases undoubtedly have an effect on the people directly working with animals; an impact that is often not fully appreciated.

The relative importance of infectious diseases in sow herds has not been studied in great detail. In a survey published in 2007 (1), the most commonly reported pathogens in sow herds were PRRSV, influenza virus, *Clostridium* type A, and *Streptococcus suis*. In production systems that reported pathogens of concern for sow herds, PRRSV ranked as number one, causing the most issues with productivity, followed by influenza, *Clostridium* type A, and *Rotavirus* (either alone or in combination with *Escherichia coli*). The ranking could have changed since then, if for no other reason than because of the emergence of porcine epidemic diarrhea (PED), which caused significant losses in naïve populations.

The objectives of this workshop are: (i) to provide personal perspectives on infection and disease control principles in pig populations, with emphasis on sow herds; (ii) to provide brief case descriptions of recent interesting case reports; and (iii) to provide an example of an alternative method for designing infection control strategies in pig herds.

A PERSPECTIVE ON INFECTION AND DISEASE CONTROL IN PIG POPULATIONS

The design of infection control strategies could be very complex but are founded on some relatively simple principles. The fundamental point is clearly expressing the ultimate goal of the control strategy. Two common goals are: (i) to eliminate an infectious pathogen from the population; or (ii) to minimize the incidence of clinical disease in the population, which could be achieved by minimizing the incidence of infection. The ultimate goal of a control strategy has direct implications on the assumptions about immunity. In situations where control of clinical disease is the ultimate goal, lower expression of clinical disease is perhaps sufficient to consider an animal as “immune”. However, when the elimination of a pathogen is the goal, immunity should be considered in a different way. In the latter situation, the simplest approach to conceptualize immunity is to consider an animal as truly “immune” only if it is able to resist infection with the pathogen that we aim to eliminate. It is important to consider that it is possible to have ongoing circulation of a pathogen in a population but no expression of clinical signs.

Some examples of strategies that control clinical disease are the use of porcine circovirus type 2 vaccines, and vaccines against *Mycoplasma hyopneumoniae* in finisher pigs.

Examples of strategies that aim to eliminate infection are PRRSV and PEDV elimination through different methods that could incorporate vaccination or other types of immunization (e.g. feedback feeding and live virus inoculation).

For situations when infection control/ elimination are the primary interest, at least five factors should be considered for the successful design of an infection control strategy. These factors could be measured at the individual, population, or environmental level: (i) duration of infectiousness in individual animals, (ii) duration and nature of immunity in individual animals, (iii) transmissibility of a pathogen in a population, (iv) survival of the pathogen in the environment, and (v) demographic characteristics of the population.

Infectiousness of individual animals may, in broad terms, be defined as the ability of an infected animal to pass infection to other susceptible animal(s). Although this seems like a straightforward concept, it is not always easy to measure. For example, the most common assumption for a PRRSV-infected animal is that it is infectious while being viremic, but the virus is known to be present in lymphoid tissues such as tonsils for prolonged periods of time. While the level of infectiousness for animals that are viremic versus animals that harbour the virus in tonsils likely differs, this is difficult to quantify. A second common assumption is that duration of infectiousness for PRRSV is on average 8 weeks at the animal level. Duration and character of immunity are important factors for infection control.

Besides the already discussed issue of protection against clinical disease or infection, another factor to consider is whether immunity is lifelong or temporary, the latter being a more common situation. Duration of immunity is a very important factor for the design of infection control; it gives a sense on how much time we have before a substantial number of animals begin to become susceptible to infection with the same pathogen again. This is essentially the time window by which infectious agents need to stop circulating in the population, and by which substantial decrease in environment contamination is required. Good estimates for the duration of immunity against infection are rarely available. They would be based on prolonged longitudinal studies, which are not always practical under field or even experimental conditions.

Another factor of importance is transmissibility. A common way of expressing transmissibility is through the use of the basic reproductive number (R_0), which is defined as the average number of secondary cases that arise after a single infectious case has been introduced in a completely susceptible population. In other words, if R_0 is 2, this implies that 2 cases are generated after the introduction of 1 infectious case in a completely naïve population. This “speed” of infection has direct implications on the appearance of clinical cases; in cases that transmissibility is generally low, disease will propagate slowly. Coupled with high turnover rates of our populations, this may not be the most desirable scenario. Quantifying transmissibility is not easy; however, there is an abundance of data that could be used for this purpose either directly or indirectly. A few possible approaches would be to estimate and use the number of new clinical cases in the beginning of the epidemic, serological results, or mortality estimates. Understanding this number (R_0) can help in understanding disease dynamics within populations. Under practical conditions, any type of feedback or immunization that involves live virus is maximizing virus transmissibility, which should result in fast transition of most animals to the ‘infectious’ stage, and then into the ‘immune’ stage in a coordinated manner. Pathogen survival in the

environment is important for almost all pathogens, and particularly for the ones that predominantly rely on fecal-oral route of transmission.

Finally, in terms of demographics, two issues can be identified. The first refers to replacement and birth rates, and the second to the internal structure of a herd. From an anthropocentric standpoint, the replacement rates in our sow herds (with annual rates of 40-50%) are extremely high, and with >25 pigs per sow per year, the birth rate is likewise high. Both of these factors contribute to circulation of infection within the herds and put high pressure on the efficacy of infection control strategies. The bottom-line is that intervention strategies aimed at controlling infection, such as immunization, need to be accompanied by some sort of demographic measures that would convert our inherently open populations into some sort of a closed population. Finally, the internal structure of modern sow barns results in different frequency of effective contacts among subpopulations. Practicing effective McRebel practices and good internal biosecurity contribute to a decrease in effective contacts.

The design of effective infection control strategies in any population can be greatly enhanced if a good understanding of all these factors is achieved. In the absence of such knowledge, clinical experience, empirical data and simulation models can be used. During this workshop, selected case studies of circulation and elimination of PRRSV, PED and influenza will be discussed.

CASE STUDIES ILLUSTRATING INFECTION CONTROL PRACTICES IN SOW POPULATIONS

Case study 1: Endemic circulation of influenza in a sow herd

Swine influenza is typically considered a simple immunizing infection, which implies that the duration of infection is relatively short, and there is not much variability in this parameter among individual animals. The infection typically results in long lasting immunity against infection with an identical virus variant. Nursery pigs represent a population that is somewhat unique from that perspective, since several studies have shown that maternal immunity could influence the pattern of influenza circulation. The success of infection control in growing pig populations is driven by the prevalence of infection at weaning, and this parameter is not well understood. We conducted a study in four cohorts of nursing and nursery pigs and two cohorts of sows during two subsequent lactations to better understand this pattern. Nursery was the period when infection was most commonly observed, but the virus was detected in all phases of production and all age groups.

Case study 2: Infection with porcine rotavirus in a herd conducting PED elimination

A large farrow-to-grow sow herd was conducting PEDV elimination (2). After initial feedback, the elimination strategy was based on maintaining a closed herd, thorough disinfection and sanitation, and controlled movement of people and fomites in the breeding herd and nursery. The feedback aimed at increasing herd-level immunity in a closed herd, disinfection and cleaning targeted the reduction of residual environmental contamination, and control of people movement aimed to reduce the indirect contact between different compartments within a barn. Nonetheless, besides all efforts, clinical issues continued as observed by unexpectedly high prevalence of diarrhea in farrowing rooms several months

after the initial outbreak. Detailed diagnostic follow-up identified that PED had been successfully controlled and that porcine rotavirus was the cause of higher than expected incidence of diarrhea in farrowing rooms (2).

AN ALTERNATIVE METHOD FOR DESIGNING INFECTION CONTROL STRATEGIES:

The use of a mathematical model to understand the frequency and size of PRRS epidemics following introduction of infected animals with different control strategies in place

As previously mentioned, some studies of interest are difficult to carry out under field or experimental conditions for either financial or ethical reasons, or both. Mathematical models have become more popular in veterinary medicine over the last few years, and some became quite powerful and able to capture different individual-level animal characteristics, contact structure, and herd flow.

The most interesting part of those models is that they allow for chance variation in regards to certain parameters of choice that could follow certain hypothesized distributions. As an example, it is debatable for PRRSV what the duration of infectiousness is at the individual level, and it is indeed known that there are between-animal differences simply from a biological standpoint. These models can consider and capture those variations. In the case of this example they account for the fact that not all animals have the same duration of infectiousness of a “magic” number of days, but that most animals will be infectious for a certain period of time (the average reported or commonly estimated period), with some “outliers” being infectious for longer (or shorter) periods.

For this case study, a model was created to describe PRRSV spread within a farrow-to-wean swine herd, and to estimate the percentage of simulations in which an outbreak occurs following the introduction of varying numbers of infectious animals (1, 5 or 10). Three scenarios were evaluated and included; no intervention (simulating a naïve herd), vaccination with live modified virus (LMV), and live-virus inoculation (LVI) with a field strain. An average 1,000-head farrow-to-wean herd was simulated, with weaning age being 21 days, four farrowing rooms, one isolation/ acclimation space, and one gestation room. The model allowed for a few parameters to vary such as duration of infectiousness, duration of immunity, and number of contacts per day (which directly relates to the transmissibility component). For each scenario (baseline/no intervention, LMV and LVI), a total of 1,000 simulations were run (3).

The main take home message from the model was that PRRSV outbreaks could occur after long periods of virus introduction when considering the fact that duration of infectiousness can be long for some animals within the population (Figure 1).

It was also observed that the frequency of no outbreaks occurring decreased as the number of infected animals introduced in the herd increased (Figures 1 and 2). When only one infectious animal was introduced into populations, for many cases, no outbreak occurred.

Finally, both LMV and LVI strategies produced a higher frequency of simulations resulting in no outbreak after the introduction of the virus, compared to the baseline scenario (no intervention).

Mathematical models are great tools for investigating hypothesis or scenarios of interest, and to describe the dynamics of infection observed under certain conditions. These models should be constructed using data collected from the field, but when these are not readily available, they allow for incorporation of uncertainty and refinement of future studies.

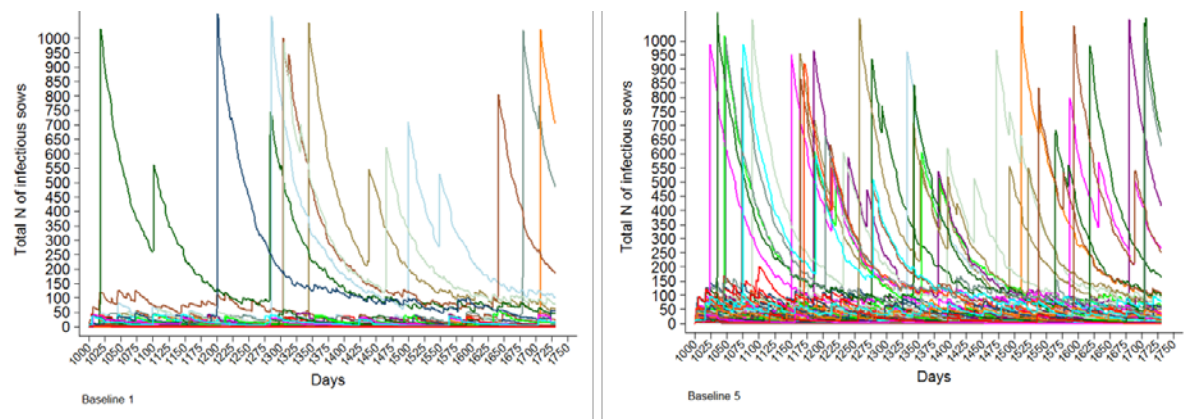


Figure 1. Epidemic curves for baseline scenario (no intervention), considering introduction of one (left) and five (right) infectious animals at day 1,000.

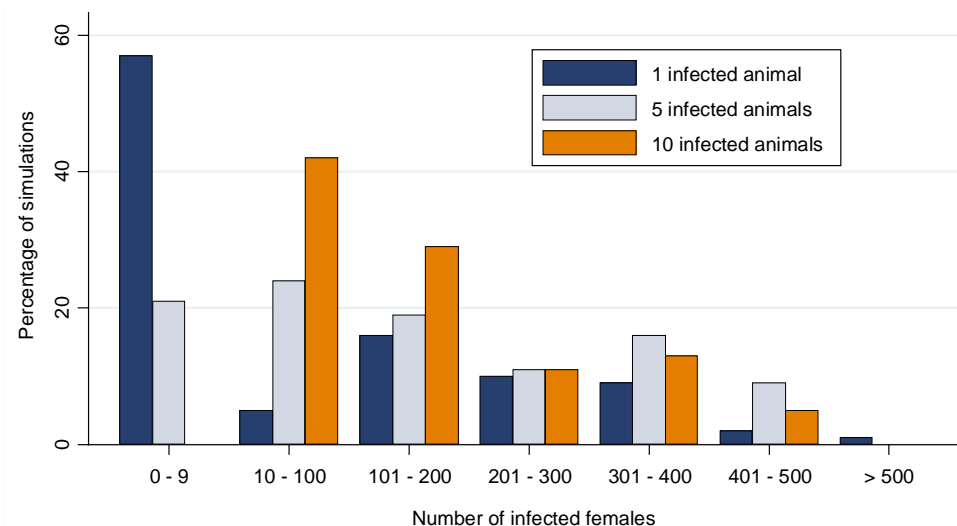


Figure 2. Percentage of simulations resulting in maximum number of infected animals (females) for cases where 1, 5 or 10 infected animals were introduced in a completely susceptible population (baseline scenario; no intervention).

CONCLUSIONS

In conclusion, a clear differentiation between infection and disease is essential to reach the goals of control or elimination of a pathogen or clinical diseases from sow herds. Details on the natural history of the disease of interest are also required, but commonly not readily available. One example of a tool available for such cases is the use of mathematical simulation models; these models can help planning control or elimination strategies while taking into consideration between-animal biological variability and pathogen characteristics that are uncertain.

ACKNOWLEDGEMENTS

SIP, Ontario Pork, OSHAB, Zoetis

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PUSHING THE BOUNDARIES OF AI TECHNOLOGY

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ABSTRACT

The widespread adoption of artificial insemination (AI) with stored boar semen has become an important production management tool in the Canadian swine industry. This workshop will review and discuss the use of select AI technologies that have the potential to add additional management strategies to production systems.

INTRODUCTION

Over the last three decades the use of artificial insemination in the North American swine industry has become widespread, with the majority of sows and gilt being bred using AI. The current AI industry is built upon the use of liquid semen stored in extenders that provide commercially acceptable fertility rates for a period of several days. For much of the last two decades, common practice has been to store extended semen at 17°C and perform 2-3 intracervical inseminations/estrus cycle using 1.5-3 billion sperm in a large volume (~70 ml). The swine industry has adopted production practices and the infrastructure required to produce, distribute and store these high quality semen doses from genetically superior boars at an economically viable cost.

This approach provides completely acceptable results, but what will the future hold? Continuous research in the areas of swine AI and semen preservation have developed new technologies or improved upon existing ones. May some of these become useful production practices in the future? Under what circumstances would their use be considered? This workshop will briefly review selected swine artificial insemination technologies that may become commercially relevant in the future – either due to improvements in the technology or as an alternative in case of production challenges.

CRYOPRESERVED SEMEN

The use of frozen-thawed (cryopreserved) boar semen dates back to the 1970s. In addition to the advantages of using liquid semen for AI, it also provides: the ability to plan inseminations, efficiencies in the import/export of genetics, control of disease transmission, long-term genetic banking, genetic transfer between nucleus herds and can function as a backup in case of a disaster (Bailey et al., 2008). Despite this, its use in commercial systems remains extremely limited, representing less than 1% of all AI matings world-wide (Yeste, 2015). There are several reasons for this. Historically, the use of frozen-thawed boar semen has resulted in lower farrowing rates and smaller litter sizes compared to fresh semen (reviewed in Knox, 2015). Boar sperm are damaged during cryopreservation procedures (Watson, 2000), which presumably accounts for the reduced life-span of thawed boar sperm in the female reproductive tract. Development of effective long-term fresh semen extenders have maximized the number of highly fertile liquid doses

that can be obtained from a boar's ejaculate, alleviating the need to develop highly efficient cryopreservation protocols. Continued research in boar sperm cryopreservation has slowly and incrementally improved freezing techniques, extender formulations, packaging methods, thawing techniques and timing of inseminations. Additional improvements are still required and will continue to be developed.

What would the challenges be in adopting the use of cryopreserved boar sperm and taking advantage of the benefits it can offer? Management techniques that minimize the differences in fertility levels achieved with frozen versus fresh semen would need to be established for each production facility or system. This would include ensuring the proper timing of insemination relative to ovulation due to the more limited life-span of the frozen-thawed sperm in the female reproductive tract. The optimum time of insemination is within 24 hours of ovulation when using liquid semen (Soede et al., 1995) but is estimated to be between 4 and 0 hours prior to ovulation when using cryopreserved semen in conventional AI (Waberski et al., 1994) or eight to four hours prior to ovulation when using deep intra-uterine insemination (DUI) of frozen-thawed sperm (Wongtawan et al., 2006). DUI insemination of boar sperm involves the use of a specially designed catheter to deposit the sperm high up within the sow's reproductive tract, near the uterotubal junction (UTJ), allowing fewer sperm to be inseminated while still maintaining adequate fertility (Roca et al., 2003). The use of post-cervical AI (PCAI), also known as intra-uterine insemination (IUI) can reduce the number of fresh sperm required for insemination (Rodriguez-Gil and Estrada, 2013). PCAI involves depositing the semen just inside the uterus and this technology has also been used with cryopreserved semen in order to reduce the number of sperm required for adequate fertility (Casas et al., 2010), although the fertility advantages are not always seen (Abad et al., 2007). This may indicate that DUI is the preferred insemination method compared to PCAI when using low numbers of frozen-thawed sperm.

Recently it has been reported that use of cryopreserved boar semen in almost 3000 conventional cervical AI matings resulted in a farrowing rate of 78.7% and a total number of piglets born of 12.5 (Didion et al., 2013). The inseminations occurred over a period of four years, and both farrowing rate and total number born increased over time, indicating improvements in adopting a new technology into the system. These results demonstrate that fertility results with frozen-thawed semen can approach commercially acceptable levels achieved with fresh liquid semen.

SEX SORTED SPERM

A potential complementary technology for the use of frozen-thawed boar sperm and/or low dose inseminations may be the use of sexed sperm. Sperm are sorted into two populations, separating those that will result in female offspring from those that will result in male. The benefits of sexed sperm to producers would be the production of more female piglets and a reduction in the number of male piglets that would need to be castrated. This technology was developed in the 1980s and the male and female bearing sperm are sorted based on very small differences in their DNA, or genetic material content. The only verified sorting system currently in use binds a fluorescent label to the DNA of the sperm and uses this label in combination with an electrical charge to physically separate the sperm into the two populations. However due to the high numbers of sperm required for optimum fertility and the low efficiency of sorting, with approximately 20,000 sperm being sorted/hour, the use

of sorted sperm is not common within the industry (Vazquez et al., 2009; Rath et al., 2015). Additionally, damage is experienced by boar sperm during sorting and once sorted they are less resistant to damage during dilution and cryopreservation (Vazquez et al., 2009; Rodriguez-Gil and Estrada, 2013). The insemination of low dose fresh sorted sperm using DUI has achieved pregnancy rates of 60-68% (Chunmei et al., 2012) but sorting and then cryopreserving boar sperm for subsequent insemination has been shown to result in early pregnancy loss (Bathgate et al., 2008). Other types of sorting technology are currently being developed including nanoparticles and microfluidic chips (Rath et al., 2015). These may have the potential at some point to improve sorting rates to the point of commercial application.

The goal is to significantly shift the sex ratio of offspring available to pig producers. How would this be achieved given the current limitations? Damage caused to the sperm during sorting and the time required to generate enough sorted sperm for a single insemination remain the largest barriers to adoption. The use of lower numbers of sperm will be required. Further developments in combining sorted sperm with low dose deep IUI or perhaps even PCAI technology may enable commercially adequate fertility levels using fewer sperm in the near future, allowing producers to choose the sex of their piglets. For nucleus systems, combining sex-sorted sperm with in-vitro production of embryos and non-surgical embryo transfer techniques may allow for maximum use of small numbers of sorted sperm and improved rates of genetic progress.

CONCLUSIONS

In the near future, adopting the use of cryopreserved and/or sex-sorted sperm in combination with low dose insemination procedures, even in limited instances, may allow producers to exploit specific advantages they offer to their particular production circumstances.

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PUSHING THE BOUNDARIES OF AI TECHNOLOGY

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ABSTRACT

It is human nature to do things you are good at, especially if they are working. Commercial pork producers are human, and at least in the realm of reproductive management that approach has been common for a long time. This paper presents a thought process of adoption of technology, specifically as it relates to artificial insemination. The intent is not to drive adoption of any technology, but to create awareness of the history of technology adoption and of emerging technologies that deserve consideration. This paper combines with that of a co-presenter to highlight technologies of past, present and future artificial insemination of swine.

PAST

Artificial insemination (AI) in swine is not a new technology, and not just in the scientific literature. Training in the technology for commercial producers in North America was offered almost 50 years ago. The first written record I have found for AI being taken to the public in the US is a January 1970 training offered to producers by the University of Missouri. Organizers touted the health benefits, the access to superior boars, ability to properly practice crossbreeding systems, etc. They offered to provide those attending with bottles, reusable Melrose catheters and everything else needed to do AI. I do not know how many attended, but very few sows were artificially bred. That was before I could read.

Ten years later the percentage of US sows mated artificially was still exceedingly low, somewhere in the low single digits. That is despite the fact that technology existed to allow it to essentially replace natural service. There were a couple boar studs offering fresh semen to be shipped anywhere in the continental US. In some countries it was estimated that nearly all sows were mated artificially. Of course there were not all that many sows in most of those countries. Those hoping to push the boundaries of AI technology in the 1970s were sorely disappointed that it was not even considered on most farms. Mating sows with AI must just not have been right for North American farms at that time.

By the mid 1990s the US industry was interested in AI, and estimates were that 20-25% of sows were being mated with the technology. AI still offered the benefits to health, genetic access, etc. that it did 25 years earlier. What had changed? Better extenders, disposable catheters, greater availability of semen, all made application easier. It didn't hurt that success had also been demonstrated not just overseas or on university farms, but on real commercial farms here in North America. It also didn't hurt that farms were getting larger, so a lot of sows were now being managed by full time pig farmers rather than farmers that just had some pigs. This specialization of labour allowed refinement of techniques. As the expectation for performance grew, adoption of AI was a natural step.

Within ten years the industry embraced the technology such that survey data showed over 90% of sows were being mated by AI by the late 1990s. Then what? In 2001 Extension swine specialists shared European data about how sperm numbers could be reduced (cut in half) by adopting a catheter that by-passed the cervix and deposited semen directly into the uterine body; intrauterine insemination or IUI. Some farms dabbled with these catheters, but VERY few used them and that boundary was essentially not pushed by commercial farms. Companies began marketing extenders that proclaimed to result in a 10d shelf life. In many cases those extenders were not successful at containing bacterial growth, so the shelf life was never realized. Nonetheless, extender technology continued to be pushed to preserve robustness of sperm cells, allowing higher fertility with older semen.

PRESENT

Now it is 2016. Where is the frontier for AI technology? It is estimated that today 1/3 of sows are mated using IUI, though it is often referred to as PCAI (post-cervical insemination) and using half the number of sperm cells used previously. That is largely attributable to demonstration of success under commercial conditions in North America. Danbred North America demonstrated the ability to achieve high female productivity in 50,000 commercial sows, and then demonstrated the genetic leverage allowed by using ½ as many boars. Impact on growth rate and feed efficiency of progeny are significant.

FUTURE

What about tools allowing a single fixed-time insemination in sows? OvuGel (JBS United Animal Health in the US; Elanco Animal Health in Canada; approved for use in the US on weaned sows) does precisely that. The ability to further reduce the number of sperm cells in 80% of matings could again profoundly impact progeny performance by allowing higher selection intensity of sires. Like most tools, not every farm will benefit from incorporating it since it has its own caveats to success. Similar products in injectable form have been for some time in Canada. Incorporation of this technology allows less time (or no time) to be spent on detection of estrus, and only half as many sow matings to be performed.

Farrowing rates approaching 90% have been realized under commercial conditions using frozen semen and hundreds of matings. Sexed semen continues to come closer to commercial application. Will the North American swine industry be ready to push those boundaries when it is time? The companion paper for this workshop goes into greater detail on these technologies.

None of these technologies are being broadly used for the majority of matings. What if they were? Using IUI/PCAI allows use of half as many sperm cells before reproductive performance is impacted. Using a single fixed time AI for sows reduces sperm cells needed for this population also, and sows typically represent about 80% of females mated. If just two of these technologies were applied to all sows the impact would be dramatic. The number of boars needed to supply semen would be reduced by 50% for IUI/PCAI. For single fixed-time AI 80% of females would be mated only once instead of twice (only approved for use in sows not gilts). That would mean another 20% reduction. Is that important? From the perspective of the sow farm, that may not seem as big a deal as it truly is to the production system overall.

If we consider a system or group of farms that represents enough sows to need 1,000 boars what is the impact? First, going to IUI/PCAI would allow culling of the lowest indexing 500 boars. Of those boars, 100 would be needed for gilts, but using single fixed-time AI on sows would allow culling of another 200 boars. The system would be capable of producing all the needed semen to achieve the same level of female productivity with only 300 boars. If the system were previously using the top ½ of available boars, under this scenario they would be using the top 15%. That would result in dramatic differences in economically important traits for the resulting progeny for whatever was in the index.

If you are new to the swine industry, hold on tight! Once we decide to embrace change we don't know where to stop. It seems entirely likely that within 20 years we will look back on the simpler times when, as an industry, we were reluctant to use IUI/PCAI, fixed-time AI, frozen semen, sexed semen, automated insemination... and you will be able to say "I remember when..."

MANAGING GENERATIONAL EXPECTATIONS

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What do you want as you transition labour, management and ownership of your farm?

Clarity of expectations...understanding how roles and responsibilities will shift.

Certainty of agreements and timelines so that equity is shared , protected for legacy.

Commitment to act. The farm can be profitable and plans are executed.

What does each generation need for success in transition ?

Traditionalist grandparents need to let go of equity. They are loyal, have scarcity issues, and are dealing with roles changing as they age. They still need meaning and purpose, as 30% are not retiring off the farm. Many need an income stream from the farm as they have not built up a personal wealth bubble to draw from.

Founders need an income stream for the next 30 years, residence, and a way to be fair to the non-business heirs. They tend to procrastinate and avoid conflict, which leaves the next generation with the pain of “not knowing ” called the neutral zone.

Founders need a mentoring mindset to let go of being the ultimate decision maker.

Successors are looking for ways to gain equity or a stake in ownership, they provide labour and want a family life, and they need to be assured that they can service debt. Most of all they want their opinion to be heard and respected. They are not willing to put in the long hours that the previous generations did. They are also very good at using technology to their advantage and working collaboratively.

Resistance for change comes from not knowing the intent, the WHY behind people’s decision making. Clarify your intent and explain why certain decisions are being made.

Build a platform of trust, honesty, accountability, commitment to act, attention to results, and conflict resolution skills to have each generation function on your transition team (see Patrick Lencioni’s *Overcoming the 5 Dysfunctions of a Team*).

Understand that resistance or pushback comes from not understanding in your head (intellectually) some of the solutions, or emotions of the heart (“I don’t like how this feels”), and the gut. Can you trust the other generations to do what they say they will do? Knowing where the resistance is coming from helps you have more courageous conversations (read Rick Maurer: *Why Don’t You Want What I Want?*).

Tools for Discussing the “Undiscussabull”...the tough issues:

1. Take CHARGE...the bull by the horns

- Take responsibility for changing you. Only you change you.
- Change is inevitable, but growth is optional.
- Timeliness is key...greater options if time is with you.

2. Come from curiosity

- I’m curious about...don’t be judgmental or defensive.

- Identify your conflict style and possible triggers. Control anger.
 - Seed common ground and “make a request”.
 - Clarify, seek information, do reality checking, brainstorm and move from positions to interest...What is important to you about that?
3. **ASK DEEPLY**
- Balance the speaking and listening...ask open-ended questions.
 - Explain describing your own feelings and interests.
 - Be soft on the person and hard on the problem...just like toilet paper!
4. **Play with possibility**
- Use a talking stick, have family biz meetings.
 - Avoid the downward spiral...be positive.
 - Don't pre-judge others' goals and dreams.
5. **Really LISTEN. “When I listen, people talk.”**
- Build understanding through checking out assumptions.
 - Explore interests and feelings.
 - Guess what is motivating the other person.
 - Check out thinkingforresults.com.
6. **Ponder and perk not prod**
- Digest, sift, and give yourself space and time to think.
 - Consider the other's perspective.
 - Ask “is there anything else?”
 - Is that right? “What would you like me to do differently?”
7. **Cultivate Trust**
- Build confidence in the relationship.
 - Walk your talk, accountability.
 - Culture of fairness, respect, commitment.
8. **Respect boundaries**
- Clear roles...dad or boss? Family or business role?
 - Guidelines for performance, jobs.
 - Be clear about expectations.
 - Confidentiality.
 - Cut gossip.
9. **We all end up in a box**
- Death will happen, come to terms with life, plan for it!
 - Face the aging process...sustain emotional & physical health.
 - Reconsider your future.
10. **Extend the olive branch**
- Create the legacy of open communication and relationship.
 - Forgiveness to be able to move forward.
 - Pass on authority and learn to let go.

Because farmers tend to avoid conflict, you need to embrace it to get change.

Constructive conflict behaviour:

- -perspective taking
- -creating solutions
- -expressing emotion...I think , I feel, I need, I want...
- -reaching out
- -delaying your response
- -adapting and being flexible

Destructive responses to conflict:

- -winning at all costs
- -displaying anger which comes from hurt, fear, frustration. Which is it ?
- -demeaning others
- -retaliating...you always get to chose your response
- -avoiding
- -yielding
- -hiding emotions
- -self-criticizing

What are your hot buttons ? What ticks you off ?

- -Abrasive behaviour...Is the criticism valid?
- -Aloof...ask open-ended questions
- -Hostile... make eye contact, control your anger
- -Micro-managing...common amongst farm managers. How can you build trust ?
- -Overly-analytical...perfectionist, what is the main thing ?
- -Self-centred...share recognition. Question things.
- -Unappreciative...Ask for what you need. Reward yourself.
- -Unreliable....keep deadlines in focus. Be organized. Have a code of conduct.
- -Untrustworthy. Protect yourself. Document.

Conflict avoidance is killing agriculture's potential. All generations need to embrace courageous conversations for planning for change.

As a Hudson Institute Certified coach I've been taught to always ask, "How old are you ?" This is not rude. This is a helpful piece of information to assess what key issues need to be talked about.

Understand that your age has certain tasks that if frustrated can cause conflict:

20's need for independence ...the decade of making it.

30's mastery of success ...exhausting with young children, mortgages...

40's taking charge...security, ownership and control

50's quality of life issues...simplify, competency

60's starting over again, building legacy...future income streams, health

70's mentoring, meaningful life

80's elder blessings...deal with death

90's daily gratitude for the legacy created. It has long been transitioned. Hand it over!

Scott Zimmer of Bridgeworks (www.generations.com) has helped me with de-coding helpful language for communication between the generations. Here's some of my gleanings from Zimmer that may be helpful for talking to your boomer parents.

The stages by ages:

Those born before 1946 are “traditionalists”. These folks have a “silent approach” to communication and typically avoid conflict. I’m a baby boomer born in 1956 with optimism and a competitive nature. **Boomers are those born between 1945 and 1964,** and there are a lot of us! We tend to be idealistic and young at heart. Perhaps your boomer father thinks he is still 21, and he hasn’t grasped the reality that he is 65! He also does not accept that there needs to be some changes in the farm’s management. He may be too focused on chores and avoids planning.

Scott Zimmer is a farm kid who is **a Generation X (Gen X’er) born between 1965 and 1979.** Gen X’ers were told that they would never do as well as their parents. Boomers saw a man walk on the moon in 1969, yet Gen X’ers saw NASA’s failure with the 1986 Challenger crash disaster. What is important to note is that the world affairs that impact us during our formative years may help shape how we perceive stress and this impacts how we communicate.

The Millennials (my children) arrived between 1980 and 1995. This group is highly driven, tech savvy, collaborative in nature, and socially adept. They want choices, efficiency, integrity and customization. One size does not fit all!

Then **Gen Edge folks (1996 onward)** are the new kids on the farm who can really process many kinds of information quickly, and may be faster at technology than the millennials.

So what does this mean for farm family communication?

1. **We all have different styles or perceptions due to the way we perceive our world, our reality.** As a boomer parent I tend to be optimistic about the future. Your Dad may be idealistic in thinking “Don’t worry, it will all work out” while you as a Gen x’er age 37 to 51 are saying “it is time for some change in ownership , NOW! Let’s get this on paper.”
2. You might need to present your ideas to your boomer parents in a different way, and with respect. **Be aware of HOW you are presenting.** Our millennial son came up with the great idea of planting hemp on our certified seed farm. His boomer father said “show me the business plan and the sales contract.”...The result is 3 years of hemp harvest with great returns (and some growing frustrations in the field).
3. **Think in terms of evolution with the intent of making things better with your communication, not revolution.** Boomers have seen tons of change in their lives, but still consider changes to their personal business on the farm with great care. They don’t want to waste money, see failure of the next generation, or divorce mucking up their ideal plan. Succession planning is a process, not a one time event , so learn to communicate to boomers about the benefits of the shifts of management, labour and ownership that you are seeking.
4. **Listen more.** All generations need to do this. Eighty percent of great communication is effective listening. Don’t make assumptions. Question everything and then listen carefully to the response. Our farm just got 3 phase power in 2015 after better research showed that the cost would be okay with the cash flow. The new ventilation system powered up in our seed plant has everyone breathing easier with less dust. This never would have happened if Manitoba Hydro had not listened to our needs. **Listen deeply. Paraphrase what you hear and feed it back to the other generations. Do not assume things. Ask “what if ?” questions and then listen!**

If you are 37 to 51 years old, and a Gen X'er, Scott Zimmer suggests you are a skeptic and immensely independent. Boomer dads need to understand this in order to speak and behave in ways that build trust and create certainty.

If you are a competitive boomer dad , perhaps it is time to remember what it felt like when you first owned something, e.g. land, and felt the independence that your millennial or Gen X'er heir is looking for now.

Respect is a good mode of communication to be transferred by all generations. Some 37-51 year old Gen X'ers may be using profane language mixed with anger that is not helping their cause of trying to get transfer agreements in place. If you are using what Zimmer calls an "unfiltered communication style", it may be time to "clean your filter" and embrace positive, non-profane language tempered with respect.

"What would you like me to do differently in this succession process ?" is a great question for all generations to ask. Gen X'er's like to question things. Asking a question is not necessarily judgment. Questions are helpful for exploration and discovery when they are asked with a tone of curiosity.

So, reflect on what your generation can do to have more effective communication with the different generations on your farm team. Twenty-three percent of millennials (ages 21 to 36) still require financial assistance from their parents. This rings true for successors who cannot afford to buy all of their boomer parent's farm assets. These successors are looking for a collaborative solution of buyouts, gifting, and fair loans from the founders.

Some boomers are spending 20 hours a week caring for aging parents on top of other roles. So if your boomer parents are really tired from role overload, consider rested times to have fierce conversations that require more energy.

Be kind, be patient, and listen well as you navigate new plans for talking things out with your boomer parents.

Read *"When Generations Collide"* by Lynne C. Lancaster and David Stillman.

What is one thing you can do today to communicate more clearly?

Here's some helpful questions for each generation on your farm.

What would you like management to do differently to help you do your job better?

What strengths do you bring to the farm?

What areas could your performance improve?

What are the key goals and expectations you have for 2016?

What skills do you need to gain and which learning plans will help you accomplish what you want ?

What do people need to let go of ?

What year do you plan to move off the farm ?

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PRACTICAL LOOSE SOW MANAGEMENT

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Forword

With moving sows to group housing, feeding them individually is a challenge. With ESF we can organize this thanks to the RFID. Over the years layouts have been developed with its ups and down. Nevertheless we are getting close to good working layouts where production and efficiency can be optimized.

Layouts

You have static group and dynamic groups with sows. It seems that dynamic groups is becoming the favourite one, for sure if sows are introduced in the group housing straight after insemination.

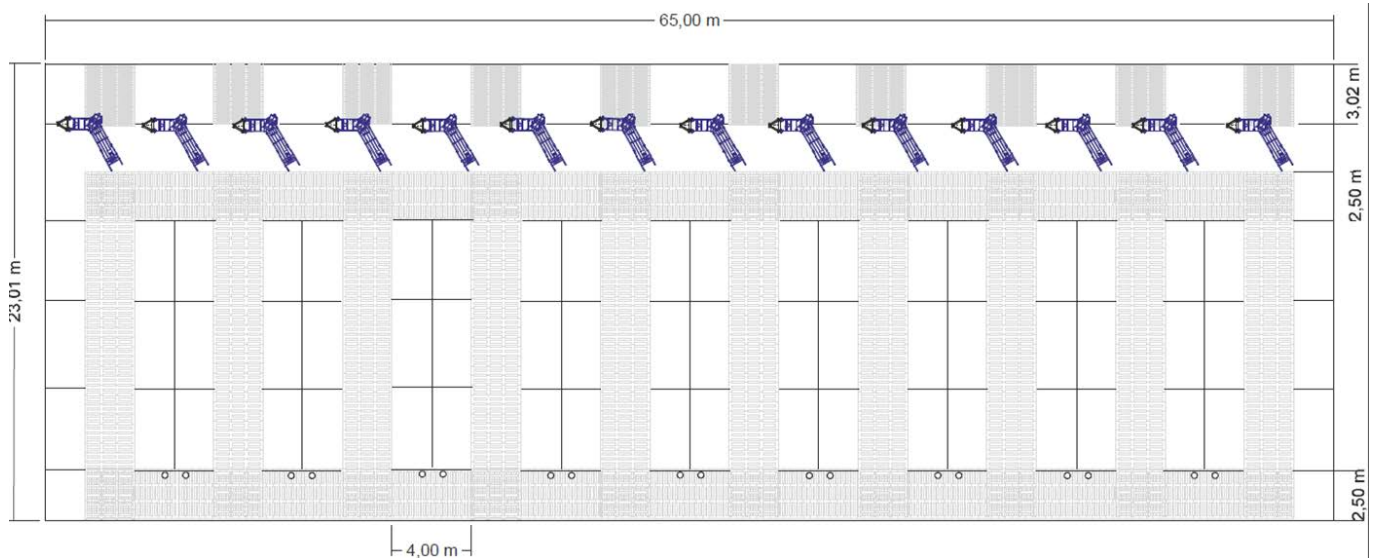


Figure 1. Layout with individual separation on every feed station (14). Top part is long separation area.

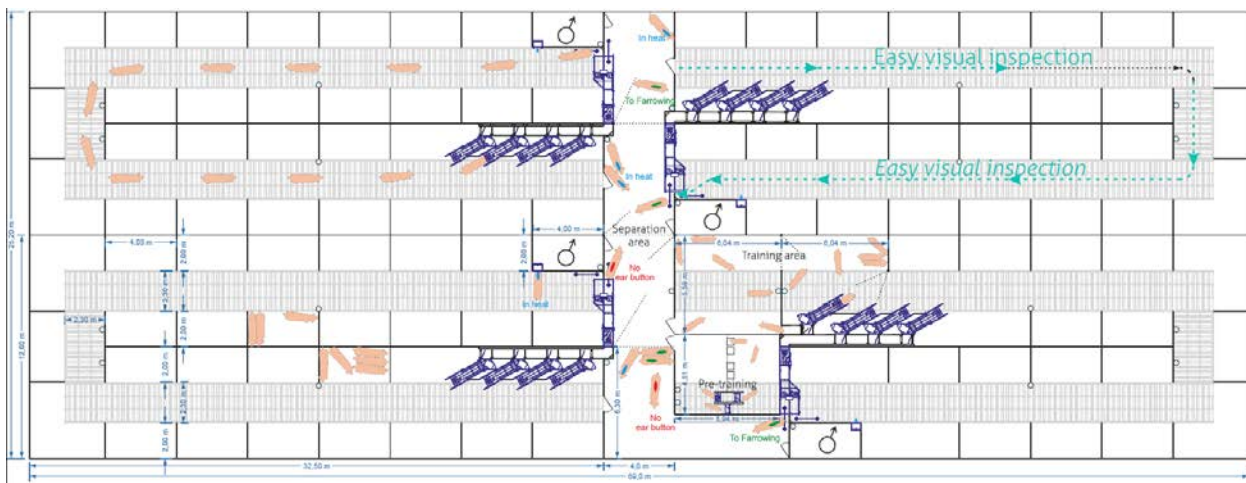
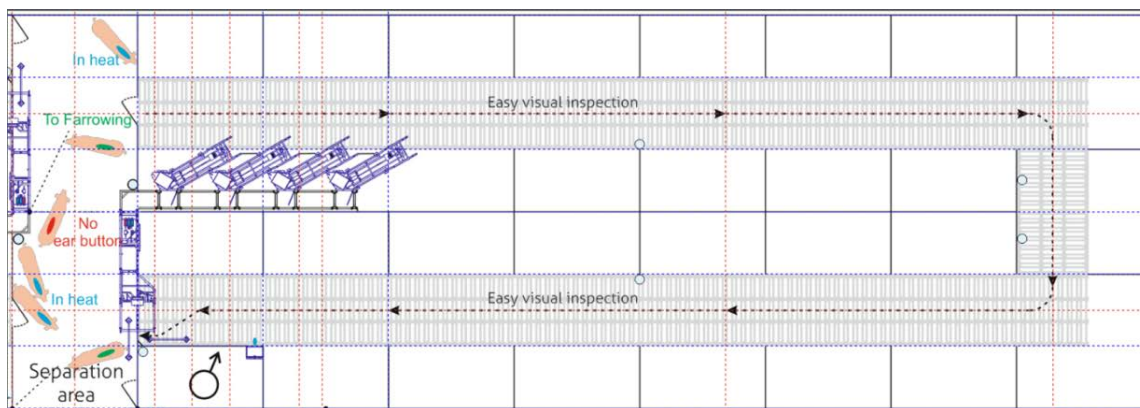


Figure 2. More practical layout 16 feed station, central separations and heat detections, with a separation area where spray marked sows in 3 colours can be seen.

Approx. 1000 sow unit, dry sow yard with 4 dynamic groups 3x198 sows and 1x185 sows/gilts:

- 1) **Automatic** heat detection (blue) market at the heat detection.
- 2) **Automatic** central spray marking (less maintenance) in separation.
- 3) **Automatic** taking out sows who did lose their ear button
- 4) **Good walking lines** for sows, takes time before they can enter the feed station again, which results in more rest (and higher production) in the group (see Report 283 Wageningen University study of visiting 70 farms with group housing).
- 5) Very short and efficient walk-ways for workers and sows who need to be transported to another area.
- 6) For checking the sows an **easy visual inspection** route which gives you perfect control, you will not miss any sow if you walk like this.
- 7) Central separation area for good overview of dry sow unit.
- 8) **Easy calibration** of the feed of feed stations.
- 9) Training and adaptation of the gilts is integrated in big dry sow place.

A good place for sows and workers which will be giving a lot of rest in the dry sow barn with optimal automated individual care and control of the individual Sows.



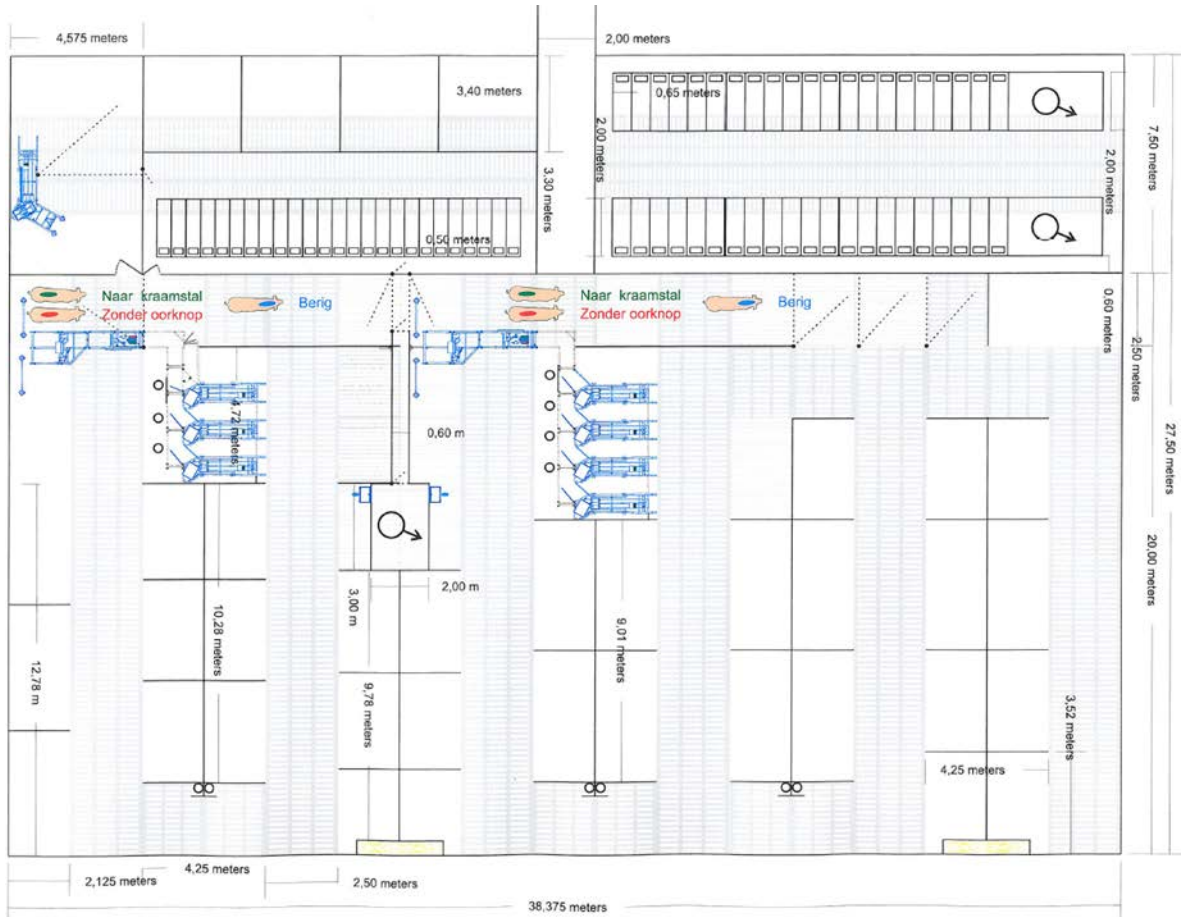
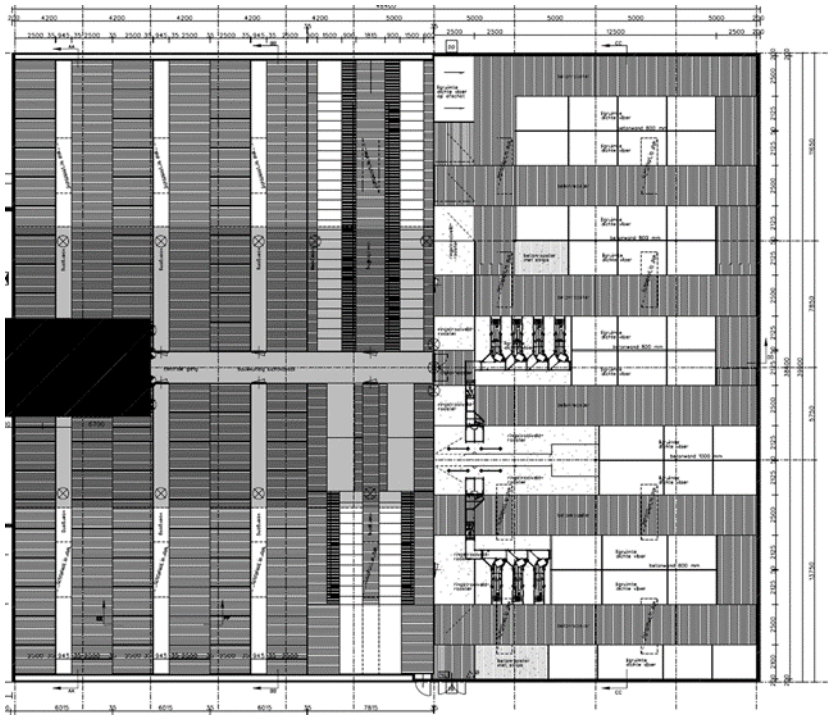
500 sow unit example

The farm of Peter and Ria Duijff in Putten (Gelderland) has 500 sows and 2500 finishing pigs. One of the biggest advantages of group housing with large dynamic groups according to Duijff is that the sows are more calm than in stalls. “Now when I enter a group, the sow doesn’t see me as coming specifically for her. That makes a difference in their behaviour. Then the farmer adapts to the sows and in the system, I never use a sorting panel. A sow taken out of the group is easy to manage.

Rest is holy (translation from Dutch means quietness in the group is the key to optimum production).

Peter Duijff from Voorthuizen is sure that one day free access stalls will be prohibited. That was the main reason he chose feeding stations in a group housing system two years ago. Duijff saw his sows demeanour change within a few weeks. They were much calmer and not anxious. The large group helps to ensure peace in the group. If you have too many animals you are always trying to catch up.





medap

The gestation barn is split into two groups. One large group of approximately 240 sows that have access to four feeding stations and a smaller group of approximately 130 sows that consists of gilts and lower parity sow that need some additional attention. The decision to use dynamic groups is based on the size of the farm. With 500 sows in 20 week groups you end up with 25 sows per group and that number does not fully utilize your feed stations. One other consideration used in the decision to use dynamic groups is that the space requirement is 10 percent lower in large groups than it is in groups less than 40 sows.

The barn is very open. Druijff enters the barn from the separation area and he has an excellent view of the stations and the lying areas of the sows. This is because of the low walls in the lying pens (60 cm or 23 ½" high). You can see and hear a lot. In the event of excess noise, you can quickly see what is going on and you don't always have to enter the pen.



The four feeding stations in the large group sit next to each other which is a standard configuration used in dynamic groups by Nedap. All activities are concentrated in small areas and the remainder of the barn is very quiet. There is very little competition at the entrance to the stations as there is always an alternate station within a short walk away. There are 50-55 sows per feed station which Druijff considers the maximum number to be effective. This situation also contributes to the peace and quiet in the pen and allows the lesser sows to have sufficient time to eat as well.

One advantage to feed stations sitting in a row is that share a joint exit leading to a separation unit. This is more efficient than each station having its own separation unit. Druijff initially had to understand how to separate the animals to fit into his work schedule. You have to organize your work and decide when you want to treat sows and then separate them first. You can't wait until the last minute to do things, you have to think ahead.



If he built a new barn, he would have the separation area completely slated as now it is partially solid and is not the ideal condition. He would put more solid floor in the lying areas so the separation area could be totally slated.

Just past the exit of the separation unit is a boar. The heat detection unit works very well according to Druijff as it registers sows when they stop and visit the boar. It's a handy tool since the system can recognize an open sow a day or two earlier than Druijff.



The boar is in the center of the barn between the two groups of sows. There is a narrow alley in the middle of the barn that Druijff can use to check and inspect the boar. The sows can be found anywhere in the barn, even by the exit from the separation unit. A clear sign of peace and comfort in the pens.



Druijff has placed a slanted wall panel in the corner coming out of the separation unit where the sows return to the group. This prevents a sow who may try to enter the exit from getting stuck in the right angle if she has to move backwards. The drinkers are placed primarily in the open area just past the exit of the separation unit. They only use five of the eight drinkers.



After leaving the separation unit, the sows can only go back to the lying areas. These are small “safe areas” in the pen. The sows have to walk completely through the lying areas before they can get back to the entrance of the feed stations.

The small group of approximately 130 sows consists of gilts and lower parity animals. This pen has only three stations which means even fewer animals per station than the larger group (40-45). By keeping these sows in a separate group, the range of the age of the animals is more uniform and also allows them additional rest time.



The sows are peaceful and satisfied on all sides. Satisfied sows are not troublemakers. Druijff is convinced that sows in large groups exhibit less aggression than sows in smaller static groups. Problems in large groups tend to solve themselves. For example, Druijff is no longer suffering from fall depression since the start of group housing.

The sows have the ability to walk around behind the lying areas. If a sow lies there, they can always turn left so there are no dead spots. There's always room to avoid the hustle and bustle of activity in the pen.



Druijff usually brings inseminated sows back into the group two days after insemination. The four day Dutch rule is not a problem for his system. The sows are placed in the separation area and with an easy to move gate, can go through the first feed station. You will benefit every day from gates that are positioned properly.

Gilts are introduced to the feed station in a separate pen. This feed station is adapted to the size of the gilt and is slightly narrower than the standard stations. Druijff helps the gilts to access the station by opening the entrance gate manually, just a little. In this barn, the gilts are six weeks old and are first housed in groups and then in stalls. Druijff puts gilts into the group following their first insemination.



Below is a layout with Straw 300 sows in a dynamic group.



SOLUTIONS TO PRODUCTIVITY CHALLENGES

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ABSTRACT

Enhancing reproductive performance of the breeding herd is a daily challenge. Today's sows and gilts are expected to farrow and wean a large number of pigs per litter and have a large accumulated number of pigs weaned per sow per year. Caretakers need to continuously be alert and look for major and minor problems that can affect reproductive performance. Although numerous factors can influence reproductive performance, this paper only deals with some of the factors affecting preweaning survival and growth rate, such as: managing colostrum intake, effect of colostrum intake on growth rate, managing mammary gland development, identification and management of non-functional mammary glands, effect of litter size on growth rate, and use of creep feed to improve the adaptation of weaned pigs to solid feed.

INTRODUCTION

The North American pork industry has made significant progress in the number of piglets born and weaned per litter and total number of pigs weaned per sow per year during the last seven years (PigCHAMP 2009-2015). Figure 1 indicates the number of piglets weaned per litter. There is a substantial amount of difference between farms ranked in the top 10% versus the bottom 10% for number of pigs weaned per litter.

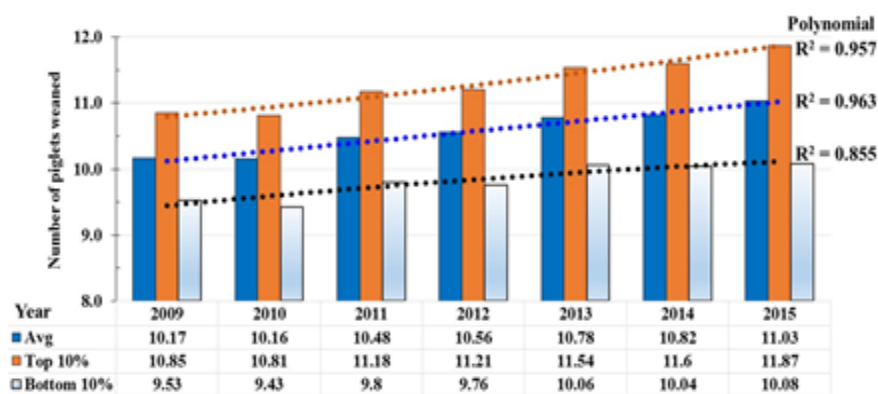


Figure 1. The number of piglets weaned per litter for years 2009 to 2015.

Scientific data indicates that an increase in number of piglets born per litter results in a decrease in birth weight of piglets and increases the within-litter variation of piglet birth weight (Table 1).

Piglet birth weight (BiW) is generally categorized as very low (< 0.8 kg), low (0.8 to 1.0 kg), normal (1.4 to 1.6 kg), and high (> 1.6 kg) [Morise et al., 2008]. Several years ago, Quiniou et al. (2002) reported that the percentage of litters with small piglets weighing less

than 1.0 kg at birth ranged from 7% in litters with 11 or less piglets to 23% in litters with 16 or more piglets.

Table 1. Effect of number of piglets born per litter on piglet birth weight.*

Item	Litter size category					P value
	≤ 9	10 to 11	12 to 13	14 to 15	≥ 16	
Number litters	195	154	276	394	579	
Average parity	2.6	2.3	2.5	2.6	3.5	
Litter size						
Total born	7.1	10.6	12.6	14.5	17.7	
Born alive	6.9	10.2	12.0	13.7	16.1	
Stillborn	0.3	0.4	0.6	0.8	1.5	
Average birth weight, kg	1.88 ^a	1.67 ^b	1.57 ^c	1.48 ^d	1.38 ^e	<0.001
Standard deviation, kg	0.28 ^a	0.29 ^a	0.32 ^b	0.32 ^b	0.33 ^b	<0.001
Coefficient of variation, % ¹	15 ^a	18 ^b	21 ^c	22 ^c	24 ^d	<0.001

¹ Coefficient of variation is a statistical measure of the distribution of data points in a data series around the average value.

* Quesnel et al., 2008.

Sixty-six percent of runt piglets (≤ 0.8 kg BiW) died during suckling. Mortality was 34% for low BiW piglets (0.81 to 1.0 kg) born alive, and less than 10% for piglets weighing ≥ 1.6 kg. As a result, 8% of weaned piglets were very low (2%) or low (6%) BiW piglets. Within-litter variation in birth weight results because of a naturally occurring phenomenon called intrauterine growth retardation (IUGR). IUGR results from alteration in nutrient supply to the fetus. Research has documented that uterine blood flow increases when litter size increases; however, blood flow per fetus decreases (Figure 2). The more embryos that manage to elongate results in more competition for uterine space. Larger implantation sites enable better development of the occupying embryo. Some elongated embryos will fail to implant and others will soon die after implantation. When an increased number of live fetuses are competing for uterine space, placental development is impaired for some of the fetuses and the growth of the fetus is retarded (van der Waaij et al., 2010).

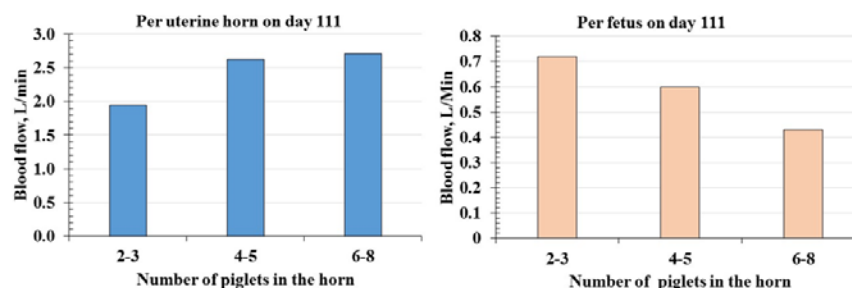


Figure 2. Influence of the number of piglets in the uterine horn at 111 days of gestation on the overall blood flow per uterine horn and on the average blood flow per fetus (adapted from Pere and Etienne, 2000).

The effect of birth weight on mortality at 42 days after birth (weaned 21 days after birth) is indicated in Figure 3 (Ferrari et al., 2014). The data clearly indicates that low birth weight increases mortality.

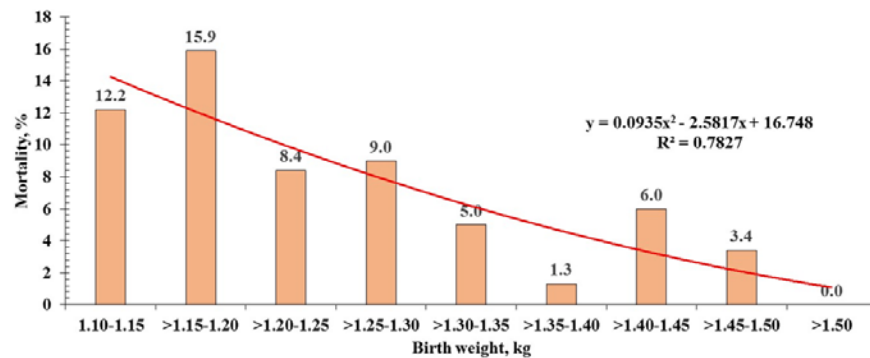


Figure 3. Effect of birth weight on mortality rate of piglets until 42 days of age (adapted from Ferrari et al., 2014).

Because of increased piglet mortality in large litter sizes and an increase in a high level of reproductive performance by sows, it has been suggested by Europeans that the piglet's and sow's health and welfare are at risk (Baxter et al., 2013; Prunier et al., 2010; Rutherford et al., 2013). Rutherford et al. (2013) suggested that genetic selection and appropriate management should be used to mitigate health and welfare issues; plus, management procedures should be used to promote piglet survival, vitality and growth.

Dr. Scorgie and I are working together during the London Swine Conference workshop entitled Solutions to Productivity Challenges. Our focus is on: (1) How can pre-weaning survival be enhanced? and (2) What factors influence weaning weight variation of pigs? In the pig production industry, the lack of uniformity in body weight of pigs within litters is an important source of concern because it is likely to affect the ease of managing the pigs in later stages of production. The objective of this paper is to look at factors that could be influencing weaning weight variation of pigs. Our approach is to generate discussion among the workshop participants; thus, the content of this paper is somewhat brief and general.

VARIATION AMONG SOWS IN MILK PRODUCTION

Various factors can influence milk production, such as: piglet birth weight, litter size, weight of piglets, litter growth rate, parity of sows (primiparous vs multiparous), heat-stress that reduces feed intake (some sows are more sensitive to heat), frequency of nursing, vitality and ability of piglets to massage (stimulate) mammary glands, water intake, health of piglets, soundness of mammary gland and nipple, and over-feeding during gestation. As indicated in Figure 4, milk yield generally peaks during the third week of lactation.

Quite frequently, first-litter sows often become catabolic and mobilize body reserves to support milk production (Eissen et al., 2003; Schenkel et al., 2010). First-litter sows are notorious for having a prolonged weaning-to-estrus interval; less voluntary consumption of feed to meet the nutritional demands for maintenance, body growth and milk production; losing too much backfat and body condition; and having a lower farrowing rate and litter size at the second farrowing.

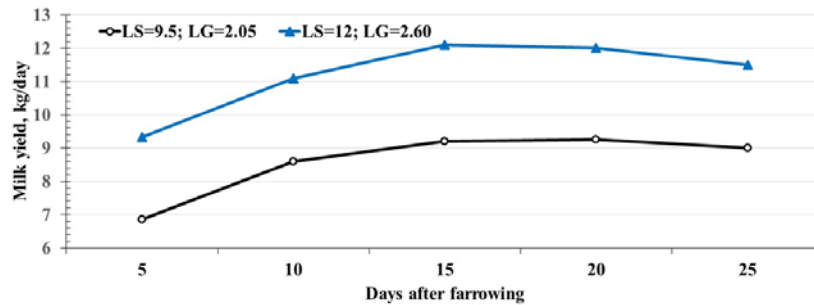


Figure 4. Shape of lactation curve when there is a change in litter size (LS) and litter gain (LG) (adapted from Hansen et al., 2012).

WHAT ARE THE SOLUTIONS FOR SOLVING A REPRODUCTIVE PROBLEM WITH FIRST-LITTER SOWS?

Variation in milk production among mammary glands

The variation in piglet weight at weaning can be influenced by differences in milk production of each mammary gland. With respect to gilts, the growth of the mammary glands is affected by the location of the gland within the underline. Mammary glands in the middle part of the underline (4th and 5th pair) grow faster during gestation (bigger in size at farrowing) compared to mammary glands located in the front (1st, 2nd, 3rd pair) and rear (6th, 7th, 8th pair) of the underline (Ji et al., 2006). Heavier or dominant pigs usually nurse the front mammary glands, which generally leaves the small or subordinate pigs to nurse the rear glands. Research has found that middle mammary glands had the greatest wet weight among glands obtained within 12 h after weaning ($P < .05$). Greater than 60% of the first four pairs of mammary glands were nursed, and less than 40% of the seventh and eighth glands were nursed by pigs during lactation (Figure 5).

Pigs that nursed the first five pairs of anterior glands gained faster than pigs nursing the remaining glands. The first five pairs of anterior glands had greater wet and dry weights, and greater protein and DNA contents compared with the remaining glands. Pigs that nursed heavier glands gained weight faster ($r = .68$, $P < .0001$), and those heavier glands contained greater amounts of protein ($r = .98$, $P < .0001$) and DNA ($r = .66$, $P < .0001$). The functional superiority of anterior and middle glands was positively correlated with body weight gain of nursing pigs (Figure 6).

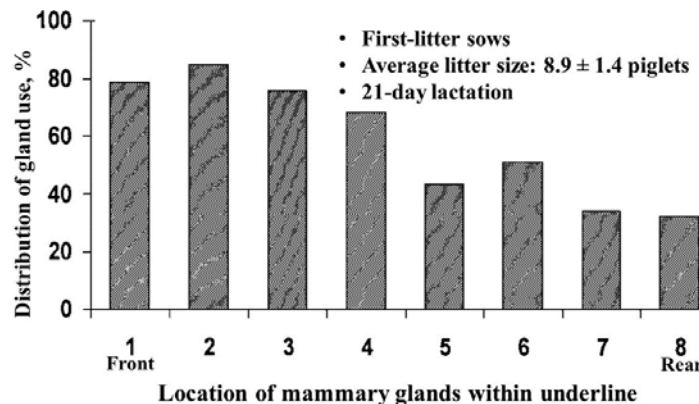


Figure 5. Distribution of gland use by nursing pigs according to the location of the nursed mammary glands (adapted from Kim et al., 2000).

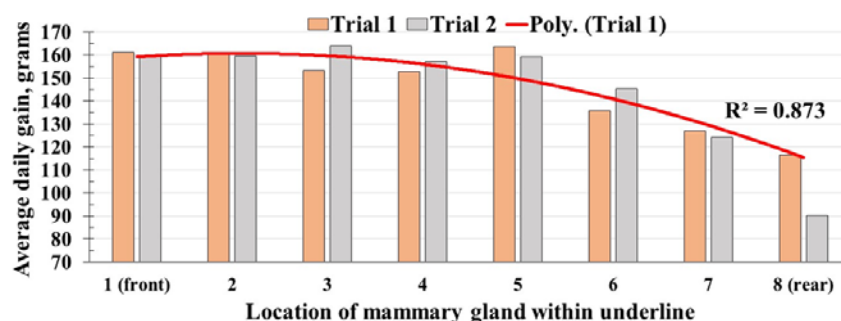


Figure 6. Average daily gain of nursing piglets by location of the nursed mammary glands (adapted from Kim et al., 2000).

Effect of piglet's birth weight on weaning weight and growth rate

During the last seven years, there has been a significant increase in piglets born alive per litter. However, there has been an increase in the number of light birth weight pigs. In addition, there has been a high incidence of pigs that fail to thrive immediately after weaning. Table 2 indicates the effect of birth weight on post-weaning growth performance. These data indicate that light birth weight and post-weaning failure is a substantial source of weight variation at closeout of a barn.

Pork producers will have to carefully manage pigs that weigh less than one kilogram at birth and pigs with poor post-weaning growth in order to maximize barn performance.

Table 2. Effect of birth weight on post-weaning growth performance (adapted from Jones and Patience, 2012).

Item	Birth weight category					Transition ADG ¹		
	<1.00	1.00-1.25	1.25-1.50	1.50-1.75	>1.75	10th	30th	70th
Number pigs	131	244	320	256	103	107	127	131
<i>Body weight, kg</i>								
Birth	0.9	1.1	1.4	1.6	1.9	-	-	-
Weaning	4.0	4.6	5.2	5.7	6.0	-	-	-
Wk 3 PW	6.7	7.3	8.0	8.5	8.6	6.7	7.8	9.0
Wk 6 PW	11.3	13.1	14.0	13.4	14.4	11.4	13.4	15.6
Wk 22 PW	97.0	100.7	103.9	105.6	108.3	99.4	102.2	107.8
<i>Average daily gain, g/d</i>								
Birth-wean	189	208	232	249	248	-	-	-
Wk0-Wk 3PW	153	153	153	153	148	87	151	218
Wk3-Wk 6PW	216	272	286	278	283	221	264	316
Wk6-Wk 22PW	781	808	830	838	857	791	814	863
Wk0-Wk 22PW	588	609	625	631	645	596	613	650

¹ The transition average daily gain (ADG) was partitioned into percentiles. Percentiles are used in statistics to indicate the value below which a given percentage of observations in a group of observations fall.

HOW CAN SMALL PIGS AND POOR PERFORMING PIGS BE MANAGED?

Number of piglets nursing the sow and weaning weight variation of piglets

Differences in body weight between individuals within the same litter increase when there is competition for teats. Under this condition, larger and more aggressive piglets are more efficient at gaining access to milk than their smaller littermates. *Are there any solutions for this problem?*

Feed intake of gilts during last part of gestation and first farrowing

The health and growth rate of piglets greatly depends on their mother's ability to produce milk.

Mammary growth during pregnancy is slow during the initial two-thirds of pregnancy and then accelerates during the final third. Gilts and first-litter sows with under-developed mammary tissue and with a low feed intake fail to obtain sufficient milk production (Ji et al., 2006; Kim and Wu, 2009). When sows were provided with 55 g lysine and 16.9 Mcal metabolizable energy daily during lactation, the growth of mammary glands was maximal (Kim and Wu, 2009).

According to Kim et al. (2013), “conventional feeding program for gestating sows does not provide sufficient proteins and minerals during late gestation causing catabolic condition to sows. Typical corn soybean meal based diets are formulated to provide 8 to 11 g true ileal digestible (TID) Lys daily to sows during the entire gestational period. A recent study (Kim et al., 2009) shows that conventional feeding program would significantly underfeed Lys during late gestation as requirements of TID Lys increase from 6.8 g/d to 15.3 g/d during late gestation. This increase in Lys requirement is due to dramatic changes in fetal tissue gain from 0.25 to 4.63 g CP/d/fetus (McPherson et al., 2004) and mammary tissue gain from 0.41 to 3.41 g CP/d/gland (Ji et al., 2006) from early to late gestation (Figures 6A and 6B).”

Variation in weight among fetuses in each litter were smaller on day 45 of gestation compared to fetal weights at 60 days and later of gestation (Figure 7a). The weight of fetuses significantly decreased from being located toward the utero-tubal junction (heaviest) to fetuses located toward the cervix (lightest) (Figure 7b).

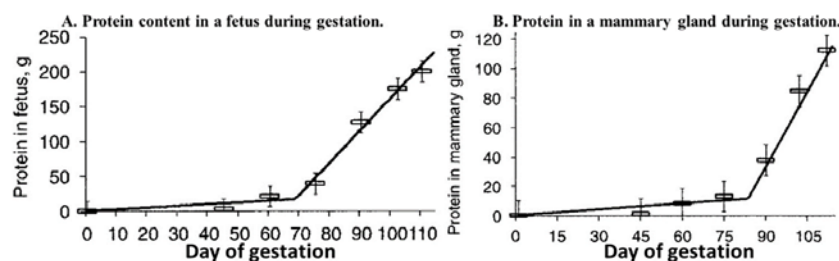


Figure 7a. Protein content in a fetus during gestation (A) and protein in a mammary gland during gestation (B) (adapted from Kim et al., 2013).

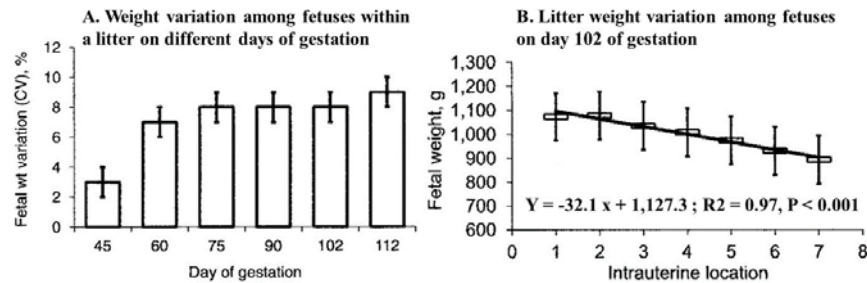


Figure 7b. Fetal growth variation by day of gestation (A) and litter weight variation among fetuses on day 102 of gestation (B) (adapted from Kim et al., 2013).

ARE THERE ANY SOLUTIONS FOR THIS PROBLEM?

Does bump feeding toward the later stage of gestation work?

Creep feeding, weaning weight and growth performance after weaning

A delay in the initiation of eating feed by piglets after weaning can lead to intestinal villous atrophy and diarrhea symptoms. Thus, weaned pigs can have reduced feed intake and lower rates of growth during the first week after weaning. The use of creep feeding is one management practice used to improve the adaptation of weaned pigs to solid feed. Nursing piglets will eat creep feed (Figure 8) and piglets eating feed will have a larger body weight at time of weaning (Figure 9).

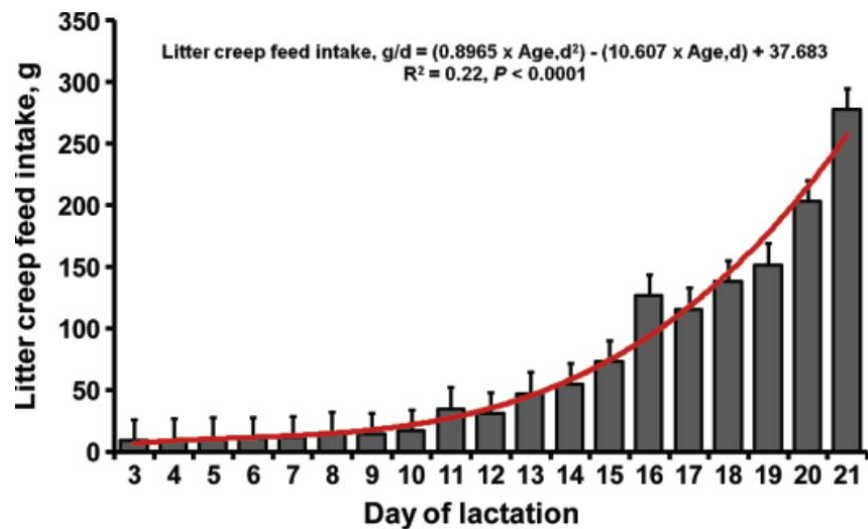


Figure 8. Daily litter creep feed intake during lactation (d 3 to weaning; 39 litters) (Sulabo et al., 2010).

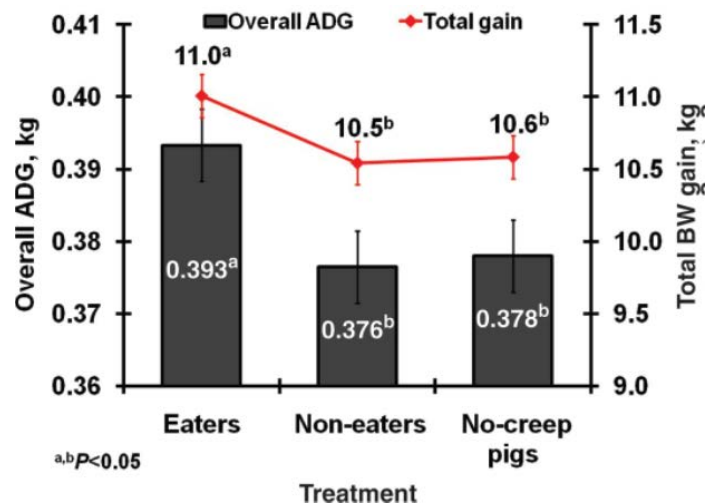


Figure 9. Overall post-weaning ADG and total BW gain (d 0 to 28) of 819 piglets according to creep feed consumption category [415 were not offered creep (no-creep); 404 were offered creep for ad libitum intake, of which 243 readily consumed creep (eaters) and 161 did not (non-eaters)] (Sulabo et al., 2010).

Does Type of Creep Feeder Influence Intake of Creep Feed?



What Response is Expected From Creep Feeding Piglets?

- Heavier pigs at time of weaning?
- Increase in percentage of pigs eating immediately after weaning?
- Increase in average daily gain from day 0 to 3 after weaning?
- Sows are weaned in better body condition?

COLOSTRUM MANAGEMENT

The greatest absorption of IgG by new born piglets occurs immediately after birth (Cabrera et al., 2013). The intestine is closed to antibody transmission in most pigs after 18 hours and in all pigs by 36 hours after birth (Westrom et al., 1984). Interestingly, there are differences in colostrum IgG concentrations between different regions of the udder. The location of the mammary glands that have a lower IgG concentrations varies. Lower concentration of IgG were found: (1) in the front teats compared to rear teats, (2) in rear teats compared to front teats, and (3) in front and rear teats compared to middle teats (Farmer and Quesnel, 2009). Regardless of the sow's colostrum concentration of IgG,

there is a substantial amount of variation in the piglet's IgG concentration at 48 to 72 hours after birth (Figure 10).

In another study, colostrum IgG concentrations declined rapidly over the first 24 hours after piglets started nursing the sow (Figure 11). In reference to the piglets, no IgG was measured in samples of piglet plasma obtained before sucking. Plasma IgG concentrations then increased ($P < 0.0001$) during the first 8 hours of sucking, remained relatively constant for the next 16 hours and then declined gradually.

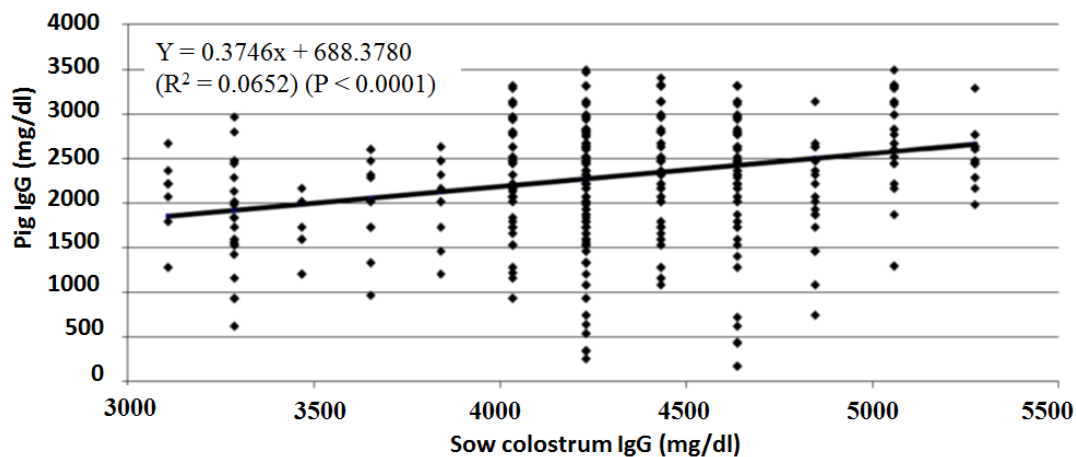


Figure 10. Effect of sow colostrum IgG concentration collected at the initiation of parturition on piglet IgG concentration 48 to 72 h after birth (adapted from Cabrera et al. 2012).

In general terms, piglets that died before weaning have difficulty taking their first breath after birth, lower birth weight, lower colostrum intake, lower weight gain during the first 24 hours after birth, lower rectal temperature, higher plasma cortisol concentration, lower plasma IgG and glucose concentrations at 24 hours after birth than piglets still alive at weaning. Numerous factors influence the amount of colostrum available per piglet, such as: 1) a short period of time (24 hours) when colostrum is available; 2) competition among piglets due to differences in body size, vitality, and number of piglets per litter; 3) the effect of birth order on amount of time available for piglets to consume colostrum; 4) colostrum is more abundantly secreted in the early phase of the colostrum period; 5) colostrum composition changes dramatically within the colostrum period, and (6) missing nursing bouts during first 24 hours of life. It is absolutely essential that ALL piglets receive their fair share of colostrum to enhance their chance for survival. The production of colostrum does not increase with litter size. Individual colostrum intake during the first 24 h after birth averages 250-300 g/d. Devillers et al. (2011) found that the ingestion of 200 g of colostrum provides passive immunity to piglets. Table 3 indicates the estimated number of piglets that a sow could provide 240 milliliters of colostrum (if each pig received their fair share). Figure 12 indicates that piglets consuming > 250 g of colostrum had a significant increase in body weight at 28 and 42 days of age.

The important question is: *Are there management practices that can be done during the farrowing process to make sure each piglet receives their fair share of colostrum?*

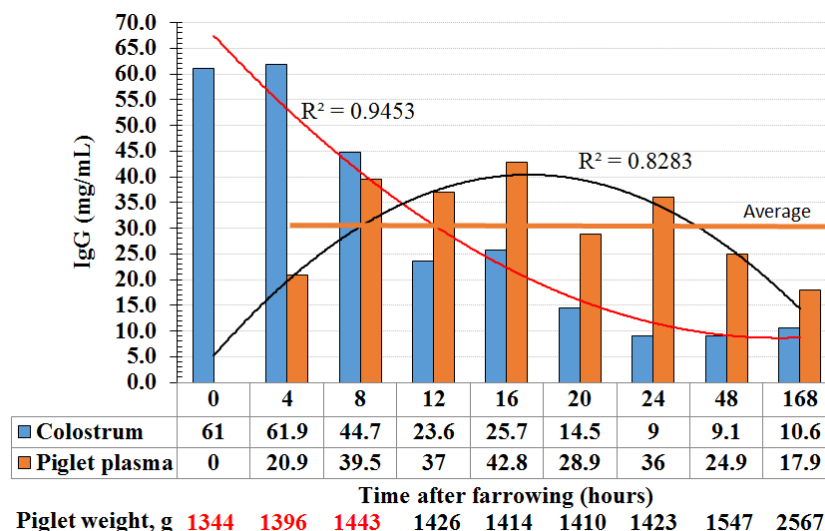


Figure 11. Changes in piglet weight and immunoglobulin (IgG) concentration in sow colostrum and piglet plasma with time after farrowing. Piglets were only allowed to nurse after all piglets were born (adapted from Bland et al., 2003).

Table 3. Colostrum produced by sows from onset of farrowing until 24 hours after farrowing and estimated possible number of piglets that could receive 240 milliliters per piglet.

Study	No. Sows	Colostrum produced per sow, mL		Number of piglets that colostrum will support at 240 mL/piglet	
		Average	Range	Average	Range
Devillers et al., 2007	40	3,600	1,900-5,300	15	8-22
Foisnet et al., 2010	12	3,930	2,830-4,640	16	12-19

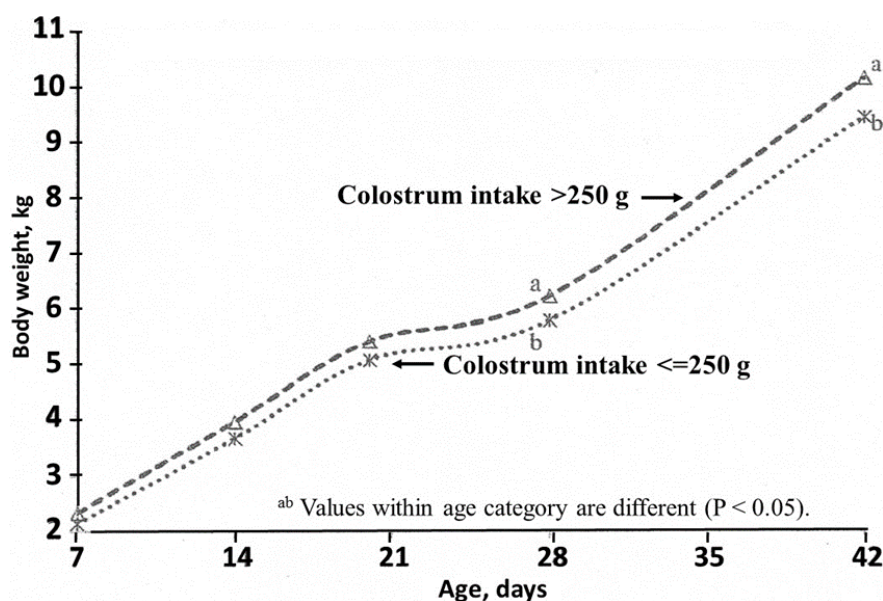


Figure 12. Effect of colostrum intake on growth of pigs from 7 to 42 days of age (adapted from Ferrari et al., 2014).

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SOLUTIONS TO PRODUCTIVITY CHALLENGES

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ABSTRACT

There can be a number of challenges to productivity on the sow farm including: labour, nutrition, genetics, health, facilities, environment, gilt management, etc. The biggest factor affecting productivity is the number of pigs weaned, (an argument could be made for the number of full value pigs weaned). I would advise owners and managers not to focus only on number of pigs weaned but also number weaned per litter. The number of sows farrowing has the biggest impact on the number of pigs weaned. The number of sows farrowing is in turn impacted the most by the number of gilts farrowing and management of the Gilt Developer Unit (GDU). Because of the broad scope of this topic, Dr. Levis and I decided in the workshop, Solutions to Productivity Challenges, to focus on two multi-factorial solutions: How can pre-weaning survival be enhanced and what factors influence weaning weight variation of pigs? If you are interested in learning more about reproductive efficiency and/or gilt management look for articles or seminars by some of the speakers here at the LSC such as Don Levis or Rob Knox. Also, look for information from George Foxcroft, Billy Flowers, Dale Rozeboom, Steve Deitz etc. I would also suggest the Sowbridge audio series from the Iowa Pork Industry Center.

Although we are not going to directly discuss gilt development, it does have an impact on piglet survivability. For example, gilts need ad lib feeding from 90 days of age to puberty to have proper mammary development. Also, nutrition in the last third of gestation affects mammary development. A lean gilt at farrowing will produce an average of 28% more milk per day than a fat gilt (Martineau et al., 2012). You want to ensure that enough gilts are farrowing to maintain the parity distribution in the sow herd to maximize productivity. A suggested parity distribution is $P_0 - 20\%$, $P_1 - 18\%$, $P_2 - 16\%$, $P_3 - 14\%$, $P_4 - 12\%$, $P_5 - 10\%$, $P_{6+} - 10\%$ (Hollis, 2007). An alternative guideline is 33% of the sows are P_0 and P_1 , 50% are P_2-P_5 . You should manage gilts so that 70% are retained to P_3 (Pinilla, 2010). For most sows, litter size generally increases to P_3 , then remains level to P_5 . Older parity sows, P_{6+} , are more likely to have poor litters with higher stillborns and lower number weaned than mid-parity sows. At the recent South Western Ontario Pork Conference, Dr. Cathy Templeton from South-West Ontario Veterinary Services suggested that producers look at the number of P_7 or older sows farrowing in a week to determine the minimum target for gilts to be bred that week to help project how many gilts are needed.

LABOUR

Our practice has clients from 175 sows to large systems with multiple sow units of 2,400, single site farrow-to-finish that raise their own gilts to farrow-to-wean sites with an off-site GDU. No matter the farm, staff have the biggest impact on piglet survivability. For the smaller farms, having enough staff is the biggest challenge. Often staff that work in farrowing have other responsibilities and cannot dedicate enough time to primary pig care. For the large systems, finding and training the right person to work in farrowing is a

challenge. Not everyone is suited to work in farrowing. Larger systems should consider having the best person work with sows at farrowing and for the first 3 days after farrowing. Have other staff process the pigs, prepare the farrowing rooms etc. Some larger sow farms will have someone working at the back end assisting sow farrowing and another person working at the front end split suckling, cross fostering etc. No matter the size of the operation many sows are farrowing unsupervised. There are a few large farms with 24-7 monitoring. Farms that batch farrow can have farrowings' closely supervised for just a few days a month. Other farms have gone to split shifts or part time employees so that someone starts working in the farrowing room first thing in the morning to check on sows that farrowed in the night. Someone else stays later in the afternoon to supervise sows farrowing. Before going home they mark the pigs that have been born from a sow still farrowing so that the morning staff does not need to focus on those pigs.

Communication with staff is important. Share production reports with them, but keep the reports simple. Focus on a few key production indicators (KPIs), but remember that KPIs are an average which can hide a tendency. So set range limits that set alarms off. Some sow farms have a war board or an erasable board in the lunch room with an ongoing summary of data, such as number BA per litter, number of sows farrowed, total number weaned, average number weaned per litter, average weaning weight etc. Some farms have just a few columns, others are more detailed. Staff can quickly view this information at break time. Communication with staff can be simple, such as a regular meeting. The farrowing room staff could sit down and review the sow records for the sows farrowing next week to identify the high risk sows that will need closer monitoring. If a nutritionist or veterinarian goes through the barn, have all staff meet with them to hear a brief summary of the visit. I find many staff are interested in areas of the barn that do not involve them. Someone in breeding/gestation is interested in piglet survivability. This helps keep staff motivated and invested in the whole operation. Protocols can be helpful, but make sure protocols are focused. I see farms with detailed protocols that are never looked at. If protocols are unrealistic then staff will become frustrated.

BENCHMARKING

Keep accurate and up-to-date records. This can help you spot trends early. Use a record keeping system that you can benchmark yourself against other producers to find areas to improve. Some producers are frustrated because they may have a smaller herd and are being compared to larger systems. Consider forming a group of like-minded producers and sharing your production information.

IMMUNITY

Disease can have a major impact on productivity. Major disease outbreaks, such as PRRS, can reduce the number of sows farrowing because of abortions and premature farrowings, and reduce the number born alive. PRRS and PED can increase Pre-Weaning Mortality (PWM). Other diseases such as influenza, although not a major disease, can cause some abortions because sows are fevered, increase PWM because sows are off feed, and have reduced milk production. Some herds have seen PCV₂ affect pigs early in the nursery and nursing piglets.

Biosecurity at most sow farms has improved with Danish Entry, improved load out chutes, clean and disinfected trucks delivering breeding stock, etc. Remember to routinely clean the “dirty” side of the Danish Entry. Keep cleaning supplies on the dirty side so that these supplies do not return to the “clean” side. This helps keep out disease. I would suggest producers do an annual biosecurity review or have their veterinarian do a regular biosecurity audit. Meet with staff regularly to review biosecurity protocols and explain why certain biosecurity measures are in place. Staff will follow biosecurity protocols better if they understand the reasons behind the biosecurity measures.

Have vaccination and treatment protocols in place and review with staff. Review your vaccination program with your veterinarian annually. I see vaccination protocols that are not being followed because someone new took over the vaccination program and was not properly trained or the protocol is not explained well. I have also seen some vaccination programs where there was duplication of a vaccine because a change in the program was not communicated well to staff.

Allow enough time in the GDU to vaccinate gilts and properly acclimatize gilts. Often these are being done to gilts too close to breeding because of tight pig flow in the GDU. If possible bring in breeder weaners or breeder feeders to allow gilts to be exposed to the different bacteria and viruses in the herd. If not possible, expose the gilts to weaner pigs such as pigs with hernias in the GDU. Many GDUs expose gilts to cull sows but cull sows often are not shedding viruses or bacteria. Make sure that gilts have enough time to cool down. For example, pigs will shed *Mycoplasma hyopneumoniae* for 240 days. Many farms bring in mycoplasma negative gilts now. If an older gilt is exposed to mycoplasma late she still could be shedding at farrowing. There is more risk she will infect pigs in her litter. This can create mycoplasma challenges in the finisher.

IMPROVING PIGLET SURVIVABILITY

Litter sizes continue to increase. Swine Management Services (SMS) showed total born/female farrowed increased from 11.5 in 2005 to over 12 in 2009 (Ketchem and Rix, 2009). This was for over 1 million sows. PigCHAMP records from 2004-2013 found that the average live born/female/year increased from 23.26 to 27.45 and the upper 10% of herds went from 26.18 to 31.7 (Marby, 2015). The December 2015 Hogs and Pigs Report showed that the number of pigs weaned per litter has been increasing at a rate of 1.8% per year. In 2015 this increase was 2.9%, a record. In 2005, U.S. producers were weaning just over 9.0 pigs per litter; by 2015 this had increased to 10.53 per litter. As litter size increases, producers are managing to wean more pigs (Figure 1).

As litter size increased there was not an increase in the uterine capacity or the placental weight of the sow. This led to a greater spread in the weight of pigs at birth. Danish researchers found for each extra pig per litter, birth weight decreased 40 grams. If the average birth weight is 1.5kg, a decrease of 40 grams per extra pig can make a significant impact (Lars and Pederson, 2014). There were more light weight pigs that would require more care at birth to survive. Also, with larger litters there is more risk of stillbirths in pigs born later in the birth order. More sows would require assistance.

As the average production increased, the difference between the top producers and the bottom producers increased. From PigCHAMP Benchmarking report comparing 2007 to

2012, the difference in 2007 between the top producers and the bottom producers continued to grow (Table 1).

There are a number of different practices that producers could implement to improve piglet survivability, the number weaned, and weaning weights.

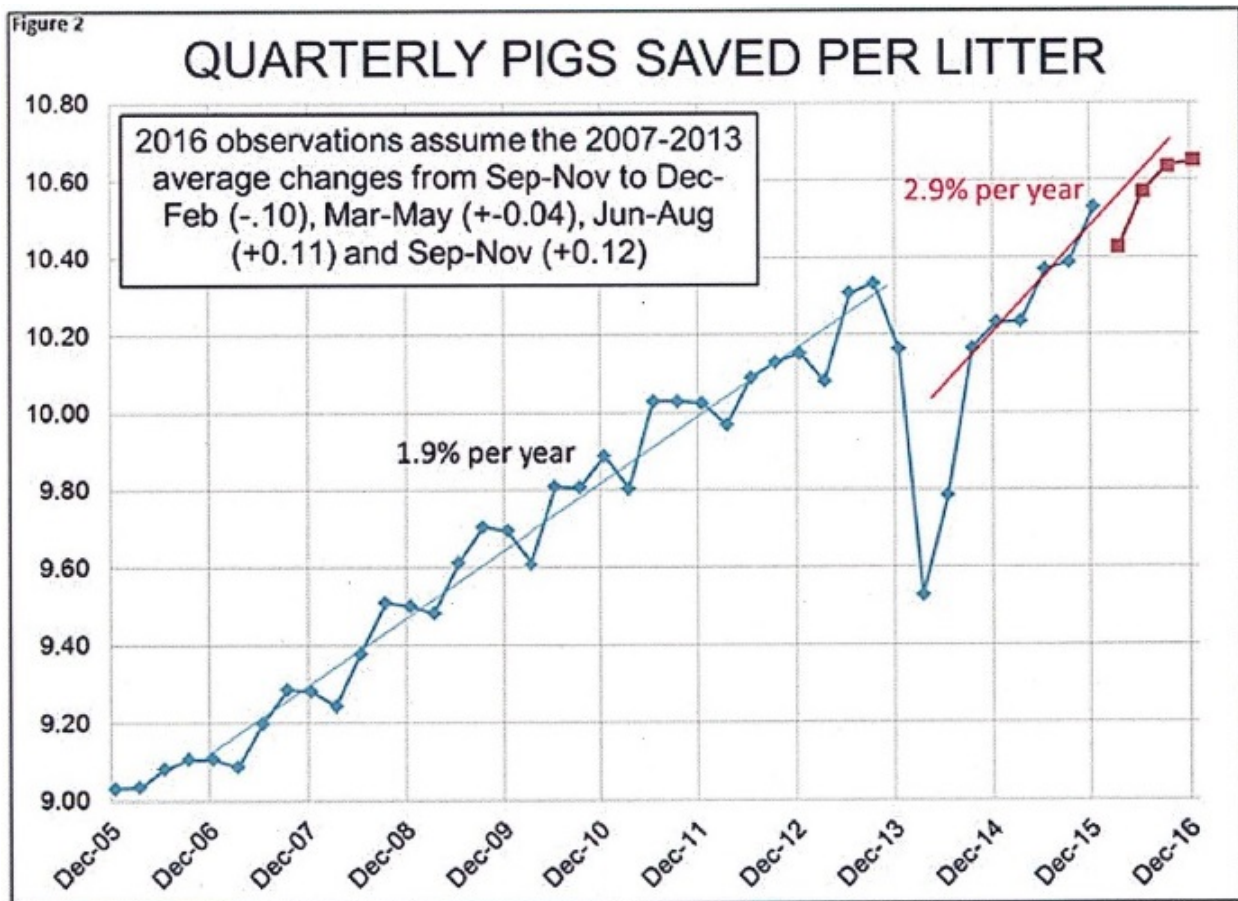


Figure 1. Quarterly pigs saved per litter.

Table 1. PigCHAMP database comparing 2007 to 2012 production data.

	2007 year summary for US herds			2012 2 nd Q summary		
	Mean	Upper 10%	Lower 10%	Mean	Upper 10%	Lower 10%
Farrowing Rate	79.06	87.8	68.6	83.57	91.25	74.88
Total Born/litter	12.34	13.25	11.3	13.35	14.82	12
Live Born/litter	11.06	11.88	10.1	11.87	12.93	10.84
% Stillborn/litter	7.7	9.81	5.31	6.59	9.18	3.92
Piglets weaned/litter	9.6	10.4	8.7	10.65	11.44	9.83
Piglets weaned/female/year	20.89	24.1	17.76	23.21	26.72	19.44

LOADING FARROWING ROOMS

Have the farrowing rooms ready to help piglet survivability. The following is a checklist to have the farrowing rooms ready:

- Rooms are washed, with a detergent or a degreaser, disinfected and dry
- Crates and rooms are warm
- Ventilation controls are set properly, a target is 20 cfm per sow
- Water nipples are functioning (water intake can increase more than 150% just before farrowing, fall again for 24 hours following farrowing, then increase to 20-35L/day) (Martineau et al., 2012)
- Have farrowing supplies ready
- Put down drying agents on the warming mats and have drying agent or towels available to dry off the piglets.
- Have Rubbermaid tubs to put pigs into when split suckling in front of the farrowing crates. Put gestation feed in the bottom of these tubs to use as feedback material later
- Identify the best crates to use for nurse sows and the best crates for gilts
- Have sow cards behind the crates so staff can identify problem sows without walking in front of the crates. Also, use these cards to record the interval between piglets being born to help identify sows that need assistance if farrowing interval is over 30mins
- Have heat lamps on and set properly
- Scrape manure from behind sows frequently
- On day of farrowing turn down the lights to keep sows calm
- Know before farrowing how many functional teats each sow has and how many functional teats are in the room to help with cross fostering

FARROWING ROOM MANAGEMENT

Farrowing and day one management are important to maximize piglet survivability, the number of pigs weaned and weaning weights. If farrowings are supervised then stillbirths can be reduced from 8 - 10% to less than 3% (Pinilla, 2010). If piglets are closely observed for the first 3 days of life then pre-weaning mortality can be reduced from 1.29 to 0.85 pig deaths per litter, because 66% of pre-weaning mortalities occur in the first 3 days (Figure 2).

Identify at risk sows before farrowing. Older sows have a greater risk of stillbirths, for example a study by Tim Blackwell (OMAFRA) found that P₂ sows had a 15% chance of having stillbirths, P₃ and P₄ – 25%, P₅ and P₆ – 35% and P₇₊ - 45% (Miller, 2015). Heavier sows are more at risk of stillbirths especially in hot weather. Heavier sows can also have prolonged labour. Extremely thin sows may be anemic and this will lead to increased stillbirths. If a sow had stillbirths in the previous litter, there is a 35% risk of having stillbirths this litter (Miller, 2015). Consider farrowing induction in those sows that have a history of a high number of stillborns.

Monitor pigs that are born in a large litter. If the total born is >12 there is twice the risk of stillborns. If a sow had a high total born last litter, identify her as a high risk sow. Watch pigs born toward the end of the litter because they are more at risk of hypoxia; 75% of stillbirths are after the 8th piglet. On average sows farrow every 30 minutes but the range

is 15 to 40 minutes. Individual sows tend to have a consistent interval. If no piglet is born within 10 minutes over the natural farrowing interval, staff should intervene (Miller, 2015). Vaginally palpate the sow to see if a piglet is in the birth canal. If no piglet is present, administer oxytocin but avoid the overuse of oxytocin. A sow should not need oxytocin before the 8th piglet farrowed and a gilt should not need oxytocin. Administer a maximum of 10 I.U. (0.5 ml) of oxytocin. Limit the number of oxytocin injections to two per farrowing.

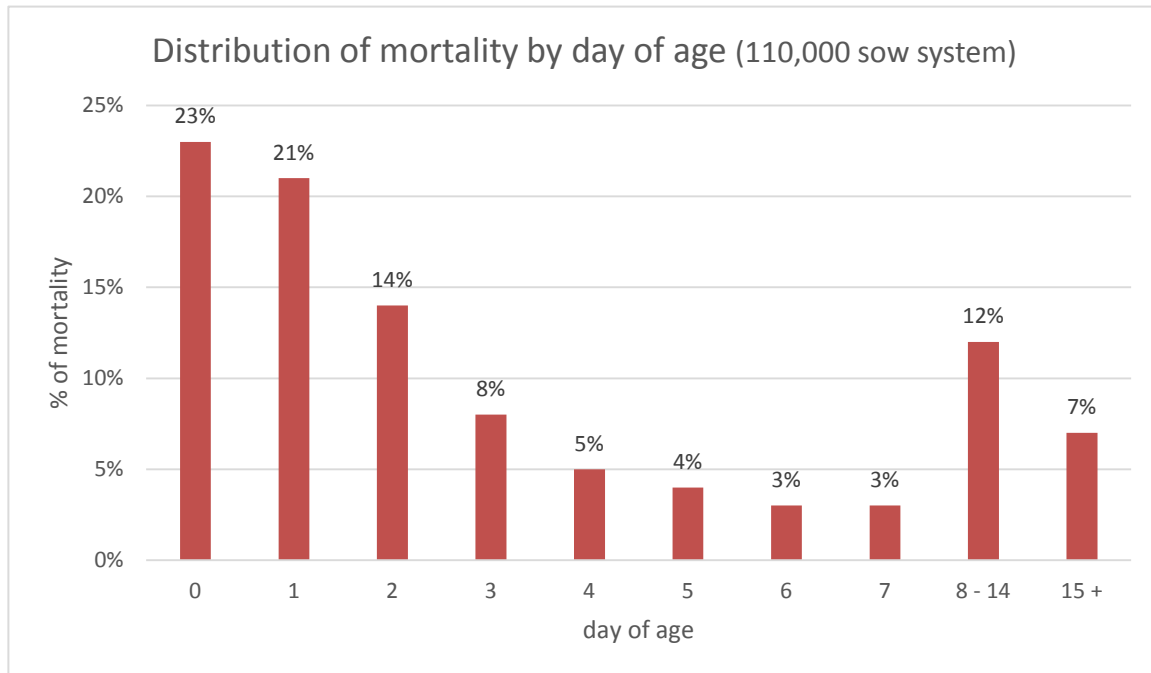


Figure 2. Distribution of mortality for 110,000 sow system (Kerber et al., 2006).

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Watch for sows with prolonged farrowings and be prepared to intervene. Discuss with your veterinarian the use of calcium injections to assist sows that have long farrowings. These sows could have a “fatigued” uterus that does not respond to oxytocin. Sows that have long farrowings, (over 6 hours), will produce less colostrum. Pre-weaning mortality (PWM) can increase from 11.8% to 21.3% in sows that have had prolonged labour.

Identify sows that were sick in gestation and required treatment. These sows may need closer supervision. Avoid stressing sows during farrowing. Stress causes the release of epinephrine which interferes with the hormones that regulate farrowing. Try not to walk in front of sows during farrowing.

First thing in the morning, farrowing staff should identify sows that have begun to farrow but there is a small number of piglets and the piglets are dried off. These sows require immediate assistance. Next dry off piglets that are wet and later start split suckling. At this time also identify any at-risk pigs to be cross fostered. Mark the at-risk pigs, this will make them easier to check when they are moved to another litter. Return later in the morning to fix the at-risk pigs and in the afternoon check that their bellies are full (Kerber-Aldous et al., 2006; Vansickle, 2013).

It is important to dry off piglets at birth to help them get to the teat faster and maximize colostral intake. Piglets have a large body surface to weight ratio and lose heat rapidly. Piglets lose heat by convection, from the movement of air, by radiation to building surfaces (for example an outside wall), by evaporation from moisture on damp skin and by conduction from heat lost from the body in direct contact with solid material. Dry piglets off with a towel or by putting on drying agents. Having a drying agent on the heat pad is not enough to quickly warmup the piglet. Consider having a heat lamp behind the sow during parturition to warm up this area of the farrowing crate. Scrape manure from behind sows in the farrowing crates a couple times a day. Pay attention to air movement in the summer when there is maximum air movement. There can be more chilling in the summer months (Kiehne, 2015).

Piglets, unlike other animals, are born with minimal energy reserves. Piglets are born with 400kJ of energy resources. In the first 24 hours, a piglet will need 900kJ for thermoregulation, maintenance and activity. Colostrum provides the missing energy for piglets to survive. A 1.5kg piglet requires 290ml of colostrum in the first 24 hours of life. Colostrum also helps warm the piglet because it is at 39°C. One study that looked at weaned pigs vs. pigs that died found that the weaned pigs consumed 333gm of colostrum vs. the dead pigs consumed 147gm (Kiehne, 2015). Colostrum provides antibodies to the piglets. Over time the concentration of antibodies in colostrum declines so it is important to make sure all pigs get colostrum as soon as possible (Figure 3).

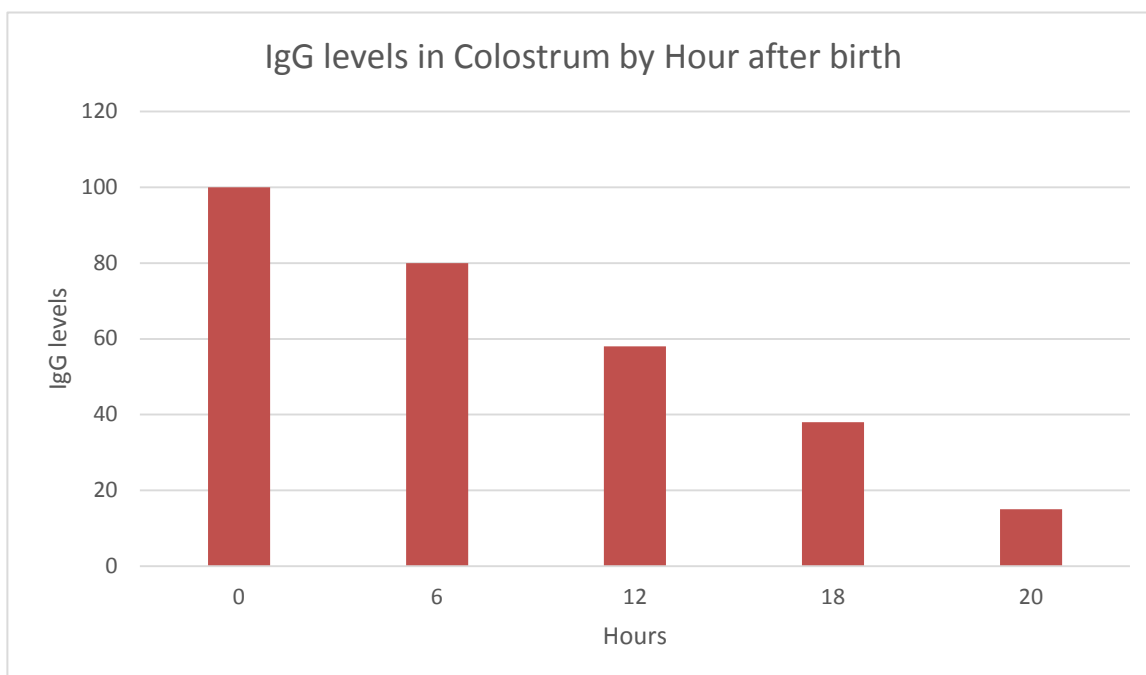


Figure 3. IgG levels in Colostrum by Hour after Birth (Martineau et al., 2012).

Researchers have also found that if a piglet consumes a small amount of colostrum then the ability of the intestine to absorb the antibodies starts to decline. It is important that piglets receive enough colostrum early.

FARROWING CHECKLIST

Have a farrowing checklist for staff to refer to and for staff training.

- Remove placenta from around pigs
- Apply drying agent or dry with towels
- Place under heat source
- Provide special care for low viability pigs: put in a warming box, tube feed with colostrum
- Split suckle large litters
- Tape splay-legged pigs
- Assist any sows with farrowing interval over 30 minutes
- Cross foster at risk pigs, pigs from large litters, small pigs, etc.
- Scrape manure from behind sows frequently
- Administer any early treatments
- Treat aggressive gilts and sows
- Late in day mark first born piglets so staff will know these piglets have had colostrum (Miller, 2015; Kerber-Aldous et al., 2006)

SPLIT SUCKLING

Split suckling is useful to ensure that pigs born later in a large litter or small pigs receive enough colostrum. One report found that split suckling reduced the number of pigs weighing less than 8lbs at weaning from 31 to 12 pigs per 1,000 and reduced the number of 9lb pigs from 83 to 47 per 1,000 (Tokach et al., 1998). Split suckle large litters early in the morning if farrowed overnight, or early afternoon if farrowed in the morning. Do not keep the pigs off the sow for more than 2 hours.

CROSS FOSTERING

Cross fostering is good tool to help improve piglet survivability. Allow pigs to nurse their own mother to improve immunity but try to have cross fostering done by 24 hours because there is less stress. After 24 hours the sow has bonded with the litter and the piglets have established the teat order. If a piglet is moved onto a teat that has not had a pig nursing for 24 hours it will be successful, if the teat has not had a pig nursing for 48 hours it will be moderately successful, but if a pig is put on a teat that has not been nursed for 72 hours it will fail (Pinilla, 2010). For litters with less than 10 pigs, cross foster pigs on. For litters with 11 to 14 pigs, leave the litter intact if possible unless there is a poor teat. For litters with over 14 pigs, cross foster off. Best candidates to move are bigger gilt piglets. Avoid multiple cross fostering of the same pig because the pig never gets established. Also, do not do a one to one transfer, (moving a heavier pig for a lighter pig). The heavier pig will be moved onto a poor producing teat (Kiehne, 2015). Do not cross foster if practicing McREBEL because of health challenges.

Use a marker to identify at risk pigs. These can be pigs that were born in the last half of the litter, didn't get enough colostrum, are small, have empty bellies, are in a large litter. Monitor the at risk pigs and be prepared to foster them back to a newly farrowed sow, a cleared sow or a weaned sow. Never move back more than 12-14 days, ideally 7. Do not foster back at risk pigs if they have full bellies.

BATCH FARROWING

A number of our clients have transitioned to batch farrowing. By adopting batch farrowing, labour in farrowing can be more focused. If sows are weaned on Wednesday then most sows in a batch start to farrow Thursday, with the heaviest farrowings on Friday and into Saturday. These farms will have someone remain late in the farrowing one or two nights to assist sows. Batch farrowing makes cross fostering easier because there are more sows to foster pigs onto.

CONCLUSIONS

As litter size has increased there are more challenges for piglet survivability. There are more light weight pigs born, resulting in more of a spread in weaning weights. Producers and farrowing room staff can adopt a number of practices such as split suckling and cross fostering to improve piglet survivability and weaning weights. Producers can train staff so that sows are properly supervised at farrowing and piglets are properly cared for. Sharing information with staff will help keep them motivated and focused. Improvement in biosecurity are helping producers keep major diseases out.

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GILT DEVELOPMENT AND LONGEVITY

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ABSTRACT

Proper introduction of replacement gilts into the breeding herd is important for maintaining animal flow and optimal pig production. Reduced sow longevity in the breeding herd shifts parity structure towards younger and less productive females. The inability to retain a high proportion of sows into the later parities requires an increase in the numbers of replacement gilts. Development of the gilt to proper maturity for fertility and longevity requires targeted windows for growth, age, weight, body condition and number of cycles. Increasing the size of the gilt pool without provision and planning for space, boar exposure, and management for growth can lead to delayed puberty, silent or weak estrus, and abnormal cycles in the gilt pool. Further, breeding gilts that are not in the desired maturity range will lead to young females that are poorly prepared for the physiological stressors of reproduction and lactation. These animals will be more difficult to manage for stability in body condition, metabolism and feed intake under the stress of first lactation.

INTRODUCTION

Throughout much of the world, inefficiency in replacement gilt entry and retention in the breeding herd continues to cause significant problems in productivity. Failure to detect pubertal estrus within 60-80 days of entry and start of boar exposure, to cycle a second time or show regular cycles after first estrus, to conceive, maintain pregnancy, or produce a desirable first litter size, have forced the industry to examine the potential sources of these problems. This long list of replacement gilt problems is serious as it affects numbers of pigs produced, flow of animals to market, and has inherent costs associated with purchase of gilt genetic value and the extended numbers of non-productive days. In the gilt pool, problems in puberty induction and regular estrus expression can eventually lead to issues with poor animal flow through the facility, crowding, inefficient use of space, remixing stress, retention of less fertile gilts, excess feed use, and reduction in value of cull gilts. Further, inefficiencies in gilt replacement often lead to problems involving retention of less productive sows, breeding of gilts that are not in the range for optimal maturity, limitations in animal space due to backups and crowding, and ultimately a shift in herd parity structure to less productive females. This pattern of premature sow failure, culling, and gilt replacement ultimately begins a cycle that is difficult to correct. The problem with the gilt is that she requires an extended period of time to reach maturity, and requires good management to identify the proper stage when breeding optimal fertility and longevity. There is a targeted range that gilts should meet for age, growth rate, body weight, and number of cycles prior to breeding that associate with fertility and longevity. In contrast, gilts mated outside of the limits, individually or in combination, fail to meet productivity targets and fail to remain in the herd past parity 3. The pressing issue for farms is how to

ensure the correct number of gilts are matured for breeding at the right time to prevent under or over development leading to early removal and reduced lifetime productivity.

GILT GROWTH

Puberty

Gilt growth rate has received much attention over many years. There is evidence that slow gilt growth rates were associated with delayed puberty. However, with emphasis on genetic selection for growth, there has been a shift to concern for fast growth rate, and its association with anestrus, delayed puberty, excessive weight at breeding, and reduced longevity. Since most gilts in the development phase are housed in group pens with *ad libitum* access to feed and water, methods to accelerate or restrict growth reflects the ability to change diet or access to feed for certain groups of gilts. The available data identify a minimum growth rate of 550 grams/day up to 170 days of age as an important factor in age at puberty (Bortolozzo et al., 2009). In contrast, high growth rates have been negatively associated with age at first farrowing in some studies (Knauer et al., 2011), but not in other studies with growth rates even at 800 grams/day (Bortolozzo et al., 2009). A study in the tropics that included ~7,000 crossbred, maternal line gilts, reported that for gilts that entered the herd at 163 days of age, average age at puberty was 200 days with a range 188-251 days. Overall, growth rate was correlated with age at estrus, but not backfat, with most of the gilts at or near 600 grams/day (Tummaruk et al., 2009). For comparison, an older study where gilt growth rates were lower at 400 grams/day, it was reported that the females with the lower growth rates were more likely to show stronger signs of estrus. In addition, pubertal heritability estimates were 0.32 for age, 0.23 for estrus symptoms, and 0.29 for vulva symptoms (Rydmer et al., 1994). The authors noted a negative association between growth rate and leanness and strong estrus symptoms. The association of growth rate with gilt fertility in some studies and not in others is perplexing, and could suggest an interaction with genetics and environmental factors, but may become irrelevant when a minimum growth is achieved.

Luteinizing Hormone (LH) has been identified as one of the leading factors associated with ovarian development in gilts. However, LH and ovarian development were not influenced by feeding level, despite effects on growth and body measures (Beltranena et al., 1993). Restricted feeding to 75% of *ad libitum* during development affected growth and body measures and delayed puberty by 1 week but without noted effects of fertility through 4th parity (Miller et al., 2011). Similar restriction in energy, while reducing growth and body weight had no effect on anestrus rate (13%) or any other fertility measure, as overall daily gain during weeks 13-25 was not below 600 grams/day (Klindt et al., 2001a). What is surprising is that restricted feeding (50, 75, 88%) from 13 to 25 weeks, followed by *ad libitum* feeding for 5 weeks prior to breeding, while having major effects on growth and body measures, had no effects on puberty, estrus, ovulation rate or embryo survival. The explanation for this was that restricted gilts ate more feed during the *ad libitum* phase to allow compensation (Klindt et al., 2001b). A recent study using modern commercial replacement gilts tested the effects of changing energy and amino acids in the diet 10-15% above or below recommendations during development. There was no change in growth or body measures (Calderón Díaz et al., 2015b) nor any effects on puberty, as gilts averaged 600 grams/day, 138 kg, and 21 mm of backfat at estrus (Calderón Díaz et al., 2015a). Diet

and feeding restriction for gilt weight control is possible without serious limits to fertility, if not employed beyond 25% of *ad libitum* and allowing time for compensation.

Gestation

Gilts are considered physiologically mature at time of breeding, but will still need to grow and gain weight during first gestation to reach a body weight that can support nursing a large litter and re-breeding soon after weaning. There is still some uncertainty on how best to feed gestating female swine and whether amounts may affect conception, embryo survival or litter traits. In prolific gilts, feeding 2 or 4 kg/d in the first week following AI had no effects on embryo numbers, survival, or on within litter weight variation (Quesnel et al., 2010). However, a study that changed protein availability during gestation (50, 100 and 250 %) affected body weight gain and the sex ratio of the litter (although there was limited data), with the higher protein diets improving sow backfat and piglet birthweight (Rehfeldt et al., 2011). There also appears some potential to improve first lactation. Mammary cells are known to proliferate in gilts from 90 days of age until puberty and then remain dormant until the last third of gestation. Much of the data fail to show nutritional effects on milk yield or piglet performance, but level of feeding may alter mammary fat accumulation as well as parenchymal (mammary duct and alveolar tissue) mass by 40% (Farmer et al., 2004).

Response to Puberty Induction

Puberty in the gilt is determined by the expression of estrus and is the key measure for gilt entry into the breeding herd. Age at puberty is an important response and has been associated with fertility and longevity. However, age at puberty can be influenced by many factors such as age at start of boar exposure, genetics, and method of boar exposure (Knox, 2004). Induction of puberty can also be accomplished using hormones such as PG600 (Knox and Wilson, 2007). From a management perspective, gilts that are older at start of exposure take less time to reach puberty but reach puberty at an older age, while earlier age at exposure advances puberty but takes a longer period of time to induce puberty. The cumulative percentage of gilts expressing estrus following start of boar exposure at 150-170 days is shown in Figure 1 and was not influenced by growth rate (Bortolozzo et al., 2009).

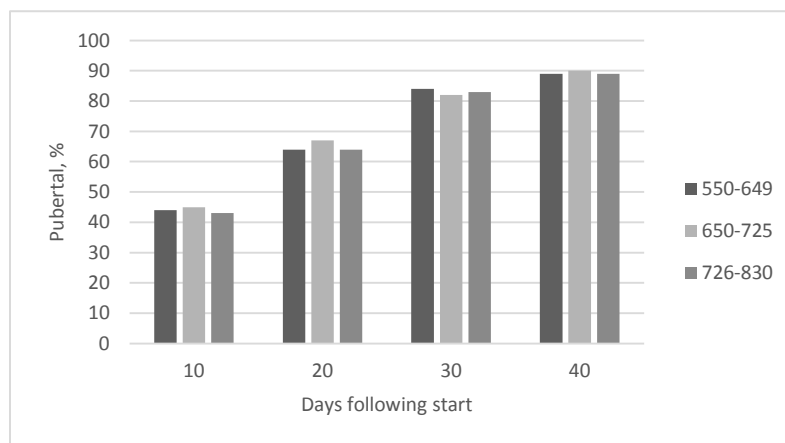


Figure 1. Percentage of gilts displaying puberty following start of boar exposure at 150-170 days of age in response to growth rate from 550 to > 800 grams/day (adapted from Bortolozzo et al., 2009).

Commercial data show that for gilts that enter the herd at 162 days of age, 70% express puberty with an average age of puberty of 211 days. There are positive associations of strong gilt estrus symptoms with gilt farrowing and longevity. Of those gilts culled at 35 weeks of age (245 d), 71% had a low strength of standing response. Increased estrus expression was associated with early puberty (Knauer et al., 2011) and would match data showing that the first third of gilts expressing puberty were more likely to return to estrus within 10 d of weaning compared to the oldest third of gilts. In addition, there were positive associations of the strength of the estrus response with duration of standing, vulva swelling and wean to estrus interval (Sterning et al., 1998). This may even match earlier studies that reported that the farrowing rate and litter size of mated gilts was related to the strength and duration (10 to >30 s) of the standing response to full boar contact (Cronin et al., 1982).

In a recent study with commercial gilts, in response to physical boar exposure starting at 160 d, average age puberty was calculated as 193 d (range: 160 to 265 d) with 91% of gilts displaying estrus (Calderón Díaz et al., 2015a). However, other analyses use different criteria and show 30% of replacement gilts selected are culled for delayed puberty (>240 d). Gilts that failed to show heat by 240 d were assessed and 61% had functional ovaries with many (50%) showing evidence of 1-2 previous cycles and with no pathology. The authors indicated that the primary problem in these gilts was a failure to express estrus (Stancic et al., 2011). The study led the authors to propose that inadequate estrus detection was the likely problem, but it is quite likely that gilt physiology may have been altered by genetic and environmental conditions during development. Sow longevity was evaluated by gilt response to physical boar exposure. Gilts that were classified as early-late responders were bred at a higher frequency at 3rd estrus (93-97%) when compared to non-select gilts (73%) or those not showing estrus by 40 days. Rate of fallout tended to be 17% higher for the differ for the non-selects but there was no effect on the proportion advancing to 3rd parity (Patterson et al., 2010). Selection for strong estrus responses may be the key to start improving gilt success and retention into later parities.

RETENTION, FAILURE AND CULLING

Assessment for how well programs for gilt replacement are working can be performed using culling information. The goal for all gilts to express puberty, be inseminated and farrow more than four litters in their lifetime happens less often than desired. Since the factors that regulate these measures are classified into genetic and environment, identifying the contribution of each is important for making advancements. Not surprisingly, the data do not agree on the contributions to each for longevity. In one study, longevity was most related to the total number of pigs born in the first litter, but not to other factors (Sobczyńska et al., 2013). In another evaluation, genetic heritability for gilt growth and body composition were estimated at 0.5 to 0.7, for soundness at 0.07 to 0.3, and for longevity and lifetime reproductive performance at 0.15 to 0.17. The authors reported that faster growth rate to 113 kg was associated with reduced longevity and reproduction with an average parity at removal of 3.6 and with 42.2 pigs born in their lifetime (Nikkilä et al., 2013). In another study, associations with longevity were positive for slower growing gilts with more backfat, early age at first farrowing, number born alive, and heavier litter weaning weights (Hoge and Bates, 2011). Evaluation of six genetic lines for longevity indicated differences by farm and month of the year for age at puberty, age at first

farrowing, and lactation feed intake (Knauer et al., 2010). These data suggest the potential for farm management to impact herd longevity. Classification of the causes of gilts failing to mate by 30-35 weeks of age, excluding those culled for unsoundness, showed that 70% had ovulated with no, or low, estrus responses identified as the primary issue. These causes were also somewhat associated with season and genetics for explaining some of the failure (Cronin et al., 1983). In Australian farms, 64% of animals were culled for reproductive inefficiency or failure, with 12% removed for locomotor problems, and of these, 42% were gilts (Hughes et al., 2010). What is interesting from a management standpoint is the discrepancy between guidelines and actual culling on farms in Japan for unmated gilts and sows (Table 1). In unmated gilts, intervals were 15 d shorter than guidelines while for mated gilts and sows were 30 d longer than guidelines, while high performance herds (top 25%), culled mated gilts and sows 10 d sooner (Sasaki and Koketsu, 2012). While the level set for the guidelines could be revised by production targets, the data provide insight into patterns for decision making for culling on farms. In a Brazilian study, culling was evaluated on farms and with the primary reasons identified as litter performance (30%), reproductive failure (23%), locomotor (12%), and old age (25%) (Ulguim et al., 2014; Table 2). These data are remarkably similar to those from other studies and illustrate the consistency for removal reasons.

Table 1. Days to culling in Japan based on general guidelines for each parity and showing actual farm data (from Sasaki and Koketsu, 2012).

	Guideline	Actual
Unmated		
P 0	300	284
P 1-3	50	23
P 4-5	44	20
P >6	34	15
Mated		
P 0	40	65
P 1-3	38	65
P 4-5	37	66
P >6	32	61

Table 2. Culling (%) on farms in Brazil by parity with reasons for removal (Ulguim et al., 2014).

	Parity					
	0	1	2	3-5	6+	Total
Litter performance	-	4.9	25.1	47.4	22.6	29.5
Reproductive failure	11.3	25.1	16.4	31.6	15.6	23.3
Locomotor	2.2	21.1	16.4	36.5	23.8	12.0
Old age	-	-	-	2.9	97.1	24.6
Misc.	1.4	29.4	15.7	33.2	20.3	10.6
Total	3.0	12.9	14.9	30.0	39.2	100

CONCLUSIONS

The data suggest a split on the impact of fast gilt growth rate on reduced longevity. Based on the large data sets and variety of farms and genetics included, it is more likely that as long as gilts are within a desired range for growth, puberty and even longevity may not be the issue. However, both fertility and longevity can be influenced by gilt parameters at time of breeding which would have consequences for gestation and lactation performance. The data also strongly suggest that very low growth rates (<500 g/d) are less likely arise in modern production systems today. These gilts would be far below weight and should not be selected for the gilt pool. Farms that do observe problems with excessive body condition as a result of fast growth rates, can choose to limit feed access or change diet as long as restriction of energy is not below 75% of ad libitum, and protein is not limiting. Several studies implicate age at first farrowing, first litter size, and litter weaning weight as key measures for gilt longevity. First litter production is an important milestone for gilts and relies on breeding decisions and management of the female. The factors involved in litter production include gilt fertility at estrus, her ovulation rate, fertilization rate, embryo survival and uterine capacity. Some of these processes are complex, and therefore farms should focus on what can be assessed and controlled by management. The considerable body of evidence implicating troublesome variation in estrus expression suggests problems in how farms deal with this problem and how estrus expression is performed in gilts. The genetic and seasonal effects on estrus symptoms also suggest that more stringent culling could be helpful. However, industry data indicates high performance is possible and not infrequent for early age at puberty and gilt puberty induction. Problems then appear to be further downstream when gilts fail to farrow early in their lifetime, when they produce a small litter in the first farrowing, or when they wean a light litter in their first parity.

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MANAGEMENT OF REPLACEMENT GILTS

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ABSTRACT

Replacement gilts represent about 20% of all farrowings on most farms. As such, they are a critical part of the production system, though in many operations all females in the breeding herd are treated similarly. This paper outlines some thoughts on the importance of gilts, selection, health management, feeding, housing and stimulating and managing puberty. Also presented is information on synchronizing estrus and how to manage 'stale gilts'.

OBJECTIVES

- identify key factors involved in gilt development
- provide general guidelines for producers to use in customizing gilt development protocols
- develop an understanding of the difference between inducing and detecting estrus

SELECTION OF REPLACEMENT GILTS

Given specialized sire/dam lines, biosecurity concerns etc., selecting finishing gilts as replacements is unacceptable. With 50% annual replacement and 2.5 litters per sow per year, one in every five litters is born to a gilt. This 20% of the females differ so much from the other 80% that some farms have dedicated entire units to breeding and farrowing only gilts that go to sow units following weaning of their first litter.

Considerations of the phenotype

While this paper is not about genetic selection, it is recognized as the first criterion in replacement gilt selection. Replacement gilts should be selected to have 14 or more evenly spaced, normal nipples. Starting with at least 14 allows the sow to have 10-12 functional nipples even with loss of productivity in some udder sections as they age. Gilts having difficulty moving are likely to get worse rather than better and should be avoided.

Predicting which gilts are likely to have mobility problems in the future is more difficult. Gilts with uneven toes tend to have more feet problems than even-toed contemporaries. Shape and angles of bones can also be important, and while it seems obvious, it must be said that producers should consciously avoid selecting gilts that are splay-footed, pigeon-toed, cow-hocked, sickle-hocked, post-legged, or buck-kneed (Figure 1). Materials are available to help identify 'normal' and common 'abnormal' conditions in feet and leg soundness in pigs.

Other physical attributes to consider include the shape and size of the vulva. A vulva that is 'tipped up' has been shown to be associated with increased infections at maturity, presumably because urine is not drained as effectively. The vulva is the only part of the gilt reproductive tract that is visible on the live animal. There is good evidence that if the vulva is small the rest of the tract is likely also small. These gilts should not be selected as they are likely to be inferior females long term.

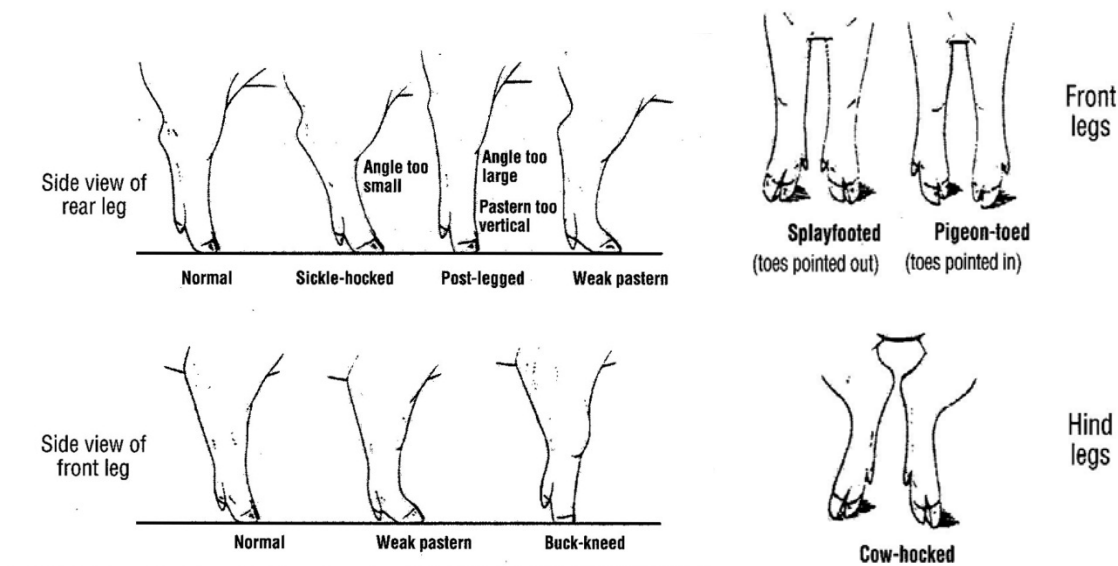


Figure 1. Drawings of normal and common aberrations in leg structure. Adapted from NSIF.

When should a replacement gilt begin to be treated differently than a market hog?

As early as 1976 data indicated that differential treatment of potential replacement females should begin no later than at birth (Nelson and Robison, 1976). Reproductive performance of gilts raised in standardized litters of six or 14 was measured. As expected piglets in the smaller litters were heavier at 14 days (one pound difference) and at weaning at 56 days (ten pound difference). Gilts were grown out and mated, and those reared in smaller litters ovulated 1.01 more eggs and had 1.2 more embryos at 25 days of gestation. The numerical difference persisted in number born alive. It appeared that nutritional/environmental stress prior to 56 days of age had detrimental effects on subsequent reproduction. The lifetime supply of eggs is established prior to 40 days of age. Other efforts since then confirm these findings where gilts which themselves have heavier birth weights and weaning weights farrow and wean larger first litters. This has been confirmed at least three more times by other investigators. The most recent confirmation was funded by a NPB Checkoff grant, and besides the first parity effects, the impact on longevity was demonstrated.

Commercial producers who select their own replacement gilts should take advantage of this effect. They might consider selection of gilts from smaller litters (ten or less piglets) or cross-fostering to enhance the maternal environment of potential replacement gilts. This could be done by loading up barrows and cull gilts into larger litters within 24 hours of birth. Selection of larger gilts within larger litters could also prove beneficial, and some experts suggest a minimum birthweight for gilts to be potential replacements, which will vary among populations. If semen is purchased, this results in very little loss in genetic progress while having a potentially major environmental positive effect on gilts.

Health Management

Producers are encouraged to work with their veterinarian and seedstock supplier to develop a comprehensive herd health management program including incoming gilts. That said, an

area of gilt management often receiving insufficient attention is isolation and acclimation. Isolation/acclimation are important whether animals are purchased or internally produced. Internal production allows greater control (or requires greater responsibility) by the producer as to scheduling, group sizes, ages, etc. Isolation/acclimation programs must minimize health differences between replacement gilts and the sow herd. Although farm specific, generally isolation consists of 30 days for replacements to be blood tested for specific pathogens, observed for signs of illness and vaccinated. Another 30 days is used for acclimation where cull animals or biofeedback are used to expose replacements to pathogens present on the sow farm. This allows the gilts to ‘get sick’ from any novel pathogens and to recover before they enter the breeding facility.

Feeding

Feeding of replacement gilts is an area where there is far from universal agreement. Details vary with genetics, health, geography, facilities, season etc. Conventional nursery and early finishing diets are normally adequate for replacement females. By the time a gilt reaches 150-180 pounds, however, feeding programs should deviate. With most modern genotypes, neither *ad libitum* feeding until mating nor feeding of conventional finishing diets will be acceptable. The former because gilts have such phenomenal growth potential that *ad libitum* feeding results in extremely large gilts, with gilts continuing growth through their second gestation. The latter because finishing diets are designed to maximize efficient lean growth for a terminal animal with no regard to longevity or to reproduction. Replacement gilts need to grow, but they also need to reach puberty, conceive, gestate, nurse a litter, and breed back quickly following weaning. In addition to their muscle growth, maturation of bones, nervous system and reproductive system must also be considered. This requires additional vitamins and trace minerals, similar to those added in a sow gestation diet, and should include biotin, folic acid and choline and higher levels of calcium and phosphorous.

Most research with modern genotypes indicates that gilts should be fed to weigh near 300 pounds by mating at 200-220 days of age. This may require limit feeding. If physically limiting feed intake is not practical, addition of bulking agents such as wheat middlings, beet pulp, alfalfa or soy hulls may be implemented to reduce nutrient density. Consult with a nutritionist to assure adequate nutrient intake is provided.

When limit feeding is implemented it is preferable to return to *ad libitum* feeding two or three weeks prior to mating. In some instances this has been shown to result in a ‘flushing’ effect and higher ovulation rate. This works best when gilts are removed from the breeding pen at mating, because *ad libitum* feeding the first four days post-mating can lead to increased embryo mortality, offsetting the gains in ovulation rate.

Housing

Housing factors to consider include space, group size, thermal modification, air quality and daylength. Space allocations provided to commodity hogs is less than ideal for replacement females. Little data exist to quantify the impact of these space differences in modern facilities with modern genetics, but it is suggested that gilts receive 10-12 square feet compared to the 8 square feet or less suggested for commodity hogs. Once detection of estrus and mating are initiated, more space is suggested. During breeding, allocations of 24 square feet are often suggested, with at least 14 provided to gestating gilts. If pregnant

females are to be housed in stalls, gilts should be acclimated prior to breeding. Data are limited, but anecdotally it seems production can be impacted if gilts have not been acclimated to stall housing for two-three weeks prior to mating.

Gilts subjected to temperatures above 80-85°F will reach puberty later. Most studies find that expression of puberty is earlier in gilts raised outdoors versus those raised in confinement. Air quality may be one contributing factor, as multiple studies have demonstrated the impact of varying air quality impairments on puberty; several authors suggest that poor air quality interferes with the gilt's ability to respond to the olfactory cues of the boar (see later section 'Managing puberty with the boar').

Group size is typically determined by factors not associated with reproduction. Most conventional group sizes fall within ranges that have been shown to have no detrimental impact on puberty; greater than three and less than 50. For practical purposes, groups of 12-20 prove ideal once daily boar exposure is initiated. This size represents groups large enough to make efficient use of time, while small enough to permit sufficient boar exposure for each gilt and allow adequate observation of each individual animal.

Another element of housing that receives a lot of attention is daylength or photoperiod. With so many gilts housed indoors it is a component that would be very simple to manipulate, but the data are far from conclusive on what is optimal. Absence of light as well as constant light are undesirable and likely impractical. If possible, it is likely best to maintain enough light to comfortably read by for 10-16 hours per day, especially when daylength is decreasing. Some evidence suggests that broad spectrum (e.g. fluorescent) lighting is better than other sources.

MANAGING PUBERTY

Managing puberty with the boar

The single greatest management tool to manipulate puberty in gilts is exposure to boars. The boar emits compounds from the submaxillary salivary gland that act as pheromones. These compounds are derived from testosterone. The standing estrus response is expressed largely in response to these pheromones, although other cues can elicit the response as well. Prepubertal gilts can respond to these pheromones by attaining puberty earlier than if they were not exposed, and a difference of two to four weeks is not unusual.

In addition to the younger age it is possible to use the boar effect to synchronize estrus in a group of gilts. Although the ideal age differs among populations, if a group of gilts receives appropriate exposure at a given age, it is possible to induce puberty in the majority of them within ten days or two weeks. If boar exposure begins too early, some gilts are not capable of responding to the boar stimuli and puberty is later and less synchronous. If gilts are too old some have already attained puberty prior to boar exposure and cannot respond to his stimulus. When considering using boar exposure to stimulate puberty it is important to know exactly what the goals of the producer are. Management will be different depending on whether the goal is to minimize age at puberty, provide the greatest degree of synchronization or to know ages of puberty for individual gilts.

The reader is likely asking themselves several specific questions: what is the appropriate age? how big should the groups be? what do you mean by 'appropriate exposure'? All are good questions and will be addressed separately below.

The appropriate age of gilts at first boar exposure varies among populations and goals. Producers are encouraged to contact their seedstock supplier for specific recommendations. Most scientific studies, however, suggest that the youngest age at puberty and greatest degree of synchrony is obtained for commercial gilt lines if daily boar exposure begins when gilts are 160-165 days old. If the goal is to know ages then, obviously, gilts must be observed daily. If the farm has a target breeding date and requires one heat-no-serve, that information can be used to inform the day of boar exposure initiation. If initiation of puberty alone is the goal, boar exposure without observation can be used. For maximum effect this would include vasectomized boars. Because of the increased injury risk this presents some farms may opt for fenceline exposure (discussed below). Some farms will attempt to provide boar exposure later (up to 200 days) to avoid the 'stale gilt' syndrome. This practice works best if other stimulatory factors can also be avoided until that age (e.g. gilts are not moved and mixed at 160 days of age). The age of the boar is also important, as it has been shown that the submaxillary salivary gland does not mature as fast as the testicle. While most boar lines are fertile at seven or eight months of age, the salivary gland is not capable of converting testosterone into pheromones until ten months of age. Boars used for detection of estrus or stimulation of puberty, therefore, should be at least ten months old.

Group size for gilt development was discussed earlier. When it comes to detection of estrus groups of 12-15 may be most appropriate. This size makes it more efficient to move groups of gilts to the boar area or dedicated heat check pens than smaller groups. When groups are larger it is more difficult to assure adequate interaction between the boar and the gilts, and it is more difficult to observe each gilt. Distinguishing between detection of estrus and stimulation of first estrus is important. Detection of estrus in gilts without getting them out of their pens (e.g. fenceline boar exposure) can be effective for detection, but is not recommended for stimulation of puberty; it is less efficient at initiating puberty, and the interaction with the person heat checking helps make handling the females easier as they are ready to be mated and moved. Fenceline contact has been shown to lead to a higher average age at puberty and a lower proportion cycling within a given time period than providing full physical boar contact. The magnitude of this difference depends on several factors including time of exposure, aggressiveness of the boar, number of gilts in the pen etc., but a difference in age at puberty of 15-25 days is common between full contact and fenceline exposure. Results of several studies showed that the difference between physical boar contact and fenceline exposure was about the same as the difference between fenceline exposure and no boar contact, suggesting that the benefit from the boar can be doubled by allowing full contact versus fenceline exposure. The value of that can be weighed against the added labour needed to provide the full contact.

'Appropriate exposure' is used here to describe the ideal way to expose gilts to boars in order to stimulate puberty. The ideal situation is that gilts are moved to a neutral heat detection area near the boar housing. This area has good lighting and footing, no distractions (e.g. nipple waterers etc.) and is large enough to allow gilts to move easily around the pen. The boar will be allowed into the pen with the gilts to provide 15 minutes of physical interaction with the gilts at least once daily, and during that time each gilt will be observed for signs of estrus. Estrus will be recorded to allow prediction of subsequent heat dates when the gilt may be eligible to be mated. Twice or three times per day exposure has been shown to further increase the boar effect, and while in some studies it was not significant, in others it more than doubled the proportion showing estrus within 20

days of initiation of the trial. It is important to recognize that these were controlled experiments and boar exposure was 'appropriate' each time. In other words, providing 15 minutes of exposure twice daily is better than providing it once, but providing five minutes three times daily is likely inferior to providing 15 minutes once.

So what happens if the farm is not able to provide 'appropriate exposure'? Stimulation of puberty is less than optimal. Many farms are not willing to commit the time to allow 15 minutes of daily physical boar exposure, and in these situations age at puberty will be later. Early age at puberty provides several advantages to an operation. Within a population, gilts that mature later tend to have lower reproductive performance, so stimulating puberty early allows later maturing gilts to be culled before they are too far over conventional market weight. Ovulation rate increases with each successive estrus through the first four or five, so stimulating early puberty can result in more eggs to fertilize. This combined with greater uterine maturity has been shown to result in larger first litters (usually 0.5 to 1.5 extra piglets). If gilts receive appropriate boar exposure beginning at 160 days and are not eligible to be mated until 210 days, there are few gilts that are anestrus when eligible to be mated, resulting in reduced non-productive days. If dates of estrus are recorded it is possible to know when to expect gilts to cycle to be mated into the schedule. This facilitates some culling decisions.

On this list of advantages of 'appropriate exposure', most of the benefits derive from having an earlier puberty, while some derive from knowing when puberty or subsequent dates of estrus are for a given gilt. The latter can only be obtained by daily detection and record keeping. Some of the former, however, is obtainable by providing less than ideal boar exposure scenarios that require less labour. For example, if a farm is not willing to spend 15 minutes daily per pen of gilts, perhaps they would consider providing fenceline exposure to a mature boar for several hours daily, with or without any observation. This would be expected to result in a lesser degree of stimulation, but obviously requires less time. It is likely that the degree of synchrony would be less and that the average age of puberty would be greater than under ideal conditions, but both would be superior to not providing any boar exposure. As mentioned earlier, this might be as much as a 15-25 day reduction in age at puberty compared to gilts receiving no boar exposure.

This leads to the important differential between using boars to stimulate puberty versus using boars to detect estrus. Providing continuous fenceline exposure has some value in stimulating puberty, but can be a disaster when attempting to detect heat. Because the standing heat response requires such intense muscle contraction, it can only be sustained by the gilt for several minutes. After this time muscle fatigue sets in, and although the gilt is still in estrus she will be unable to display such for one or two hours when her muscles have had time to relax. Research suggests that detection of estrus is most efficient in the mornings, although the reasons have not been clarified. It is likely that gilts are less distracted, especially if detection of estrus is performed at the same time daily.

Gilts that fail to cycle

The normal distribution for puberty means a few gilts cycle early, perhaps before boar exposure, a lot cycle in the middle, and a few cycle late. Producers frequently want to know what to do with those that cycle late, or non-cyclers. There is a reason they cycled late, and in many instances the best thing to do is to cull these gilts. There are occasions, however, when the gilts were fed properly, are healthy, received adequate boar exposure,

and still failed to cycle, but it is necessary to use them to reach breeding targets. There are two options to initiate cycling in these gilts. The first is to apply an acute stressor such as moving or mixing with strange pen mates. This frequently stimulates puberty in a proportion of these gilts. The second option is pharmacological intervention with a product to stimulate follicle growth such as PG-600™ (Intervet). This product will initiate follicular growth and ovulation in many of these gilts.

What about stale gilts?

Stale gilts is a term used in the field to describe gilts that exhibited puberty, for some reason were not mated, and at some point ceased to express estrous cycles. Examination of the ovaries of these gilts shows that most of them are, indeed, anestrus, having several two mm follicles but no large follicles or corpora lutea (CL). The reason for this phenomenon is not known, although it appears to be exacerbated by confinement housing. Assuming that other conditions are normal (i.e. body condition, health etc.) treating these animals like gilts that failed to express puberty (i.e. acute stress or PG-600™) seems to result in significant re-initiation of normal, fertile estrous cycles. In these gilts reproductive performance is expected to be normal.

Getting gilts bred on schedule

Since a gilt is used to replace a sow, having the gilt express estrus and conceive to farrow on the same schedule as the sow she is replacing is the ideal. Getting gilts to show estrus at the appropriate time is no easy task. Farms that farrow weekly have greater flexibility, but not absolute. Maintaining a large enough gilt pool to provide sufficient cycling gilts each week may be a poor use of facilities, labour and gilts. While there is not room in this paper to thoroughly cover synchronization of estrus, it is a critical area of managing replacement gilts and will be briefly discussed here. The reader is encouraged to consult other sources for greater detail.

Use of boar exposure to stimulate puberty was discussed earlier and how the greatest degree of synchrony typically occurs when first exposure occurs at 160-165 days of age. To get a group of gilts to fit a schedule, however, less synchrony may be desirable. If, for example, a farm receives replacement gilts monthly but farrows weekly, an attempt is made to breed an equal number of gilts as replacements each week. In this scenario a group of gilts randomly cycling may fit the schedule better than a tightly synchronous group. The alternative is to initiate boar exposure to a subset of the gilt pool at different times so puberty is staggered.

There are two hormonal compounds used for synchronizing estrus on commercial swine farms in the U.S. Each of them is a potentially useful tool, but has limitations. The one longest on the U.S. market is PG-600™ (Intervet). This is a combination of gonadotropins given as a single injection that serves to stimulate the growth and ovulation of follicles on the ovaries of non-cyclic females. It is only useful if the gilts are prepubertal, and they must be physiologically capable of cycling. Response on some farms is quite good (Table 1), but there are other farms that fail to find it useful (perhaps the gilts were already cycling or perhaps they use it on inferior gilts such as those they were unable to stimulate naturally). A fertile estrus is expected in 50-80% of prepubertal gilts within 5 days of treatment.

The second product, approved in the U.S. in 2003, is Matrix™ (same as Regu-mate in Canada; Merck). This is an orally active progestin, that when fed daily acts like the C.L. on the ovary; i.e. it makes the gilt ovary not grow new follicles. It is topdressed in an oil solution for 14 days. It is imperative that each gilt receive her full daily dose to prevent development of cysts on the ovaries. Results from several studies indicate that, when fed to cycling gilts (see Figure 2), 85-98% will display a fertile estrus 4-9 days after the last daily feeding. The compound in the oil is absorbable through the skin of people, so care should be taken when handling, especially by women. High conception rates are common following this protocol.

Table 1. Considerations for pharmacological intervention strategies.

Product	Gilt status to be effective	Comments	Results
PG-600™	noncyclic (prepubertal or 'stale')	one injection	varying
Matrix™	gilts must be cycling	individual feeding 14d	very reliable

*some farms have less success, perhaps because gilts already have cycled without farm's knowledge

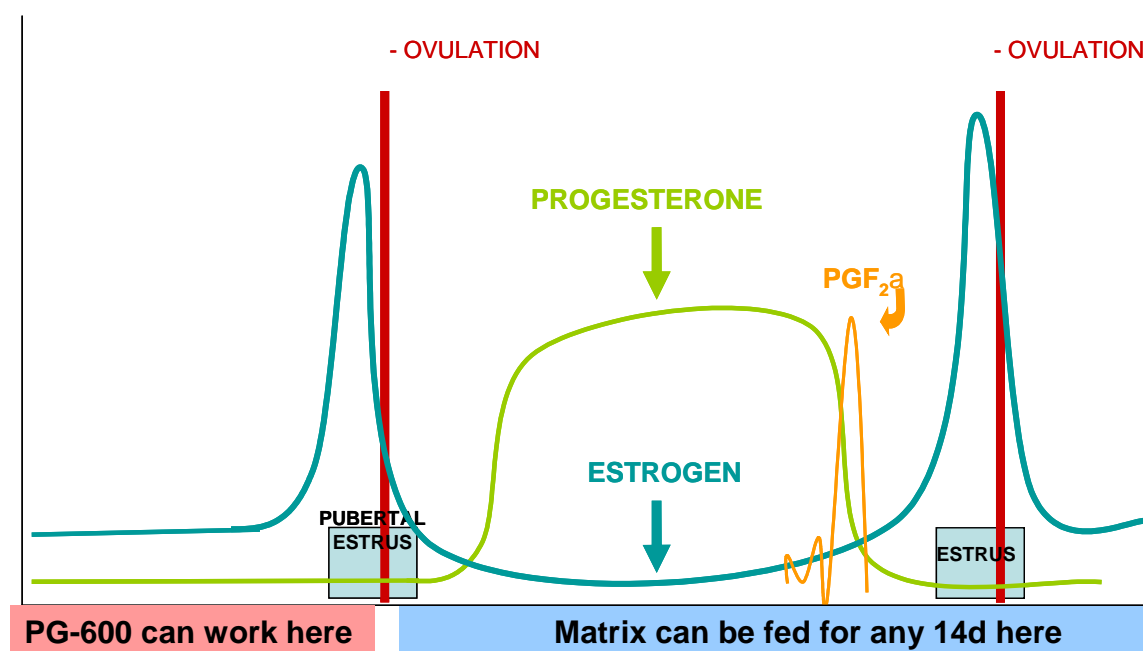


Figure 2. Porcine estrous cycle and timing of pharmacological interventions (adapted from Isom).

After mating

Mated gilts of modern genotypes are still not mature, typically being at perhaps 55-65% of mature body weight. Efforts should be made to treat them as such. While individual housing can delay puberty, mated gilts perform well in this environment or in stable groups. If they do not receive a separate diet from older sows, special attention should be given to their growth and condition during gestation. At farrowing the parity one female is at a disadvantage to older sows. While demands on her are high for maintenance, milk production and body growth, her feed intake is lower than that of older sows. Extra efforts should be made to enhance feed intake in parity one females during lactation. The ideal

situation would be to provide a separate diet formulated with the consideration that feed intake is less than for older sows. In reality managing two diets in the same room proves challenging, but many farms are able to help parity one females by providing a topdress that results in greater nutrient density in the feed consumed.

A timeline to consider

Each farm is different because of variation in geography, genetics, facilities, labour and philosophies. As such each must develop their own gilt development protocols and timelines. Below (Figure 3) is a suggested starting point that can be modified to individual scenarios.

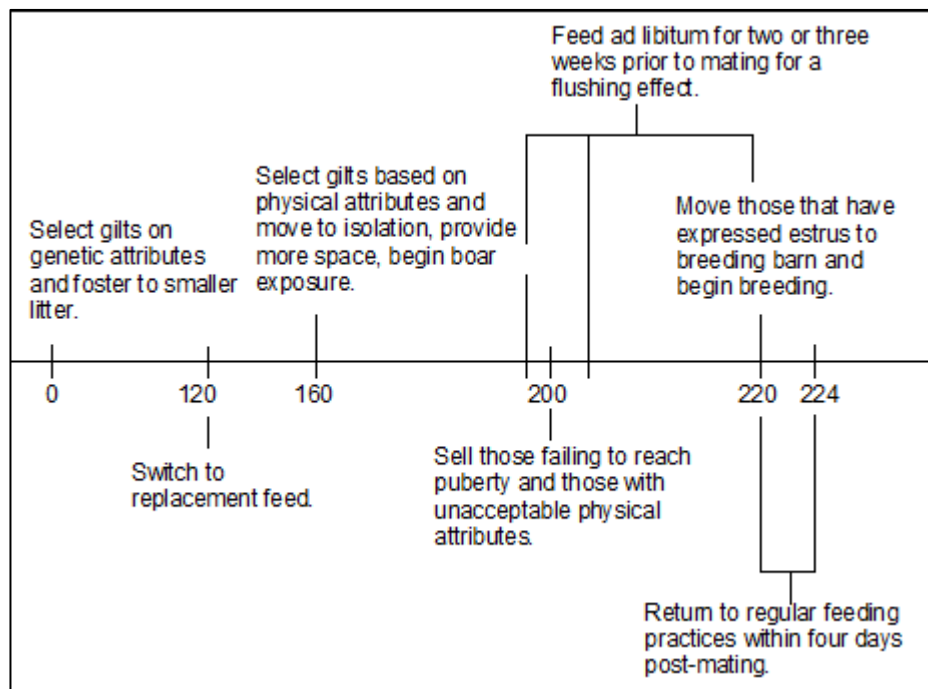


Figure 3. Activities that may be performed at various age in days for replacement gilts. Use of PG-600 as early as 160 days of age or Matrix after gilts are known to be cycling may be considered to synchronize estrus.

SUMMARY

Gilts intended to be used as replacements should be treated as the special animals that they are. After all genetic decisions are made, they should be provided a better nursing environment, more space and separate feeds than their counterparts intended for market. Health should be monitored and actively managed. Through the strategic use of mature boars, the gilt age at puberty should be stimulated early and recorded. They should be mated and managed after mating as parity one females, receiving a different diet than older sows. These steps require extra time, and in some cases greater investment, but the payoff in long term productivity can be great.

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Day 2: Wean to Finish – Main Sessions

SUSTAINABLE INTENSIFICATION: HOW TO PRODUCE MORE ANIMAL PROTEIN WITHOUT DEPLETING NATURAL RESOURCES

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The global livestock production is projected to double the current rate by 2050 (Smith et al., 2007) and the majority of this growth will be occurring in the developing world (Wood et al., 2006). The assessment of the holistic impacts of food animals in the context of global and regional environmental policy and food security becomes imperative. Much of the growth in the global livestock sector will occur in areas that are currently forested (i.e., parts of South America and South East Asia). It has been well established that significant reductions of carbon sequestering forests will have large effects on global climate change.

Livestock production in most countries of the developed world (e.g., United States and Europe) has a relatively small GHG contribution within the overall carbon portfolios, dwarfed by large transportation, energy, and other industry sectors. In contrast, livestock production in the developing world can be a dominant contributor to a country's GHG portfolio, due to the developing world's significantly smaller transportation and energy sectors. In the United States, transportation accounts for at least 26% of total anthropogenic GHG emissions compared to roughly 5.8% for all of agriculture, which includes 3.4% associated with livestock production. However, in countries like Paraguay, the trend is likely reversed because of Paraguay's much smaller transportation and energy sectors, and a relatively large livestock sector, which might contribute to more than 50% of that country's carbon footprint.

The fact that land-use changes associated with livestock (i.e., forested land converted to pasture or cropland used for feed production) are a significant source of anthropogenic GHGs in Latin America and other parts of the developing world is apparent. However, it is likely that any kind of land-use change from the original forestland will lead to great increases in global warming. FAO (2006) attributes almost half of the climate-change impact associated with livestock to the change of land-use patterns. Latin America has the greatest pool of 'unused but suitable' land that is currently covered by forests but could be turned into agricultural crop or livestock production (Bruinsma, 2003). In 2000, Latin America had 203 million hectares arable land in use and 863 million hectares of unused land suitable for cropland (19% in use) (Bruinsma, 2003). Over the same time span, developed countries had 387 million hectares arable land in use and 487 million hectares of unused land suitable for cropland and livestock (44% in use) (Bruinsma, 2003). Transformation of land from forest to agriculture has occurred in the developed countries centuries ago to make way for industrialization and general societal wealth. Not surprisingly, numerous developing countries are currently attempting to develop their economies by turning economically marginal land into production.

The United States and most other developed countries have not experienced significant land-use change practices around livestock production within the last few decades. Instead, over the last 25 years forestland has increased by approximately 25% in the United States and livestock production has been intensified (concentrated geographically), thus

reducing its geographical footprint. Modern livestock production has experienced a marked improvement of efficiencies, leading to significantly decreased numbers of animals to produce a given amount of product that satisfies the nutritional demands by society (Capper et al., 2009). Intensification of livestock production provides large opportunities for climate change mitigation and can reduce greenhouse gas emissions from deforestation, thus becoming a long-term solution to a more sustainable livestock production.

Comparing numerous international reports (CEC, 2005; EPA et al., 2006; FAO 2006) shows large agreement with respect to emission predictions from most livestock related categories. There is general consensus that as a direct GHG category, enteric fermentation in ruminants and manure management are the most important categories within livestock production. Categories like on-farm fuel use or feed production are dwarfed by emissions coming from the animals and their manure.

Overall, growing demands for animal protein could strongly increase GHG emissions from agriculture. However, knowledge exists to improve efficiencies in livestock production, which dramatically reduces GHG per unit of production. What is called for is sustainable intensification in animal agriculture, coupled with technology transfers from developed to developing countries, to supply a growing demand for animal protein using sustainable and modern production practices.

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GETTING READY FOR THE NEXT DISEASE: SENECAVIRUS A EXPERIENCES

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INTRODUCTION

Senecavirus A (SVA, formerly known as Seneca Valley virus) is a 30 nm non-enveloped RNA virus. It is the single member of the Senecavirus genus within the Picornaviridae family.

SVA has been isolated from pigs since 1988 and it was reported as picornavirus-like particle until 2002, when the virus was isolated from contaminated cell medium and named Seneca Valley virus (Reddy, Burroughs et al. 2007). In fact, SVA has been identified as a non-pathogenic virus in human with oncolytic properties and its efficacy on cancer therapy is currently being evaluated in human clinical trials (Rudin, Poirier et al. 2011). The first whole genome sequence became available in 2008 (Hales, Knowles et al. 2008).

Investigations in the veterinary medicine field suggest that SVA circulates among domestic animals at least since the late 80's. Anti-SVA antibodies have been detected in cattle, mice and pigs (Knowles, Hales et al. 2006). SVA has been suggested as a causative agent of idiopathic vesicular disease in pigs (Singh, Corner et al. 2012, Leme, Zotti et al. 2015). Briefly, the World Organization for Animal Health (OIE) and most governments consider reportable vesicular diseases in swine Foot and Mouth Disease virus (FMDv, Aphtovirus), Swine Vesicular Disease virus (SVDv, Enterovirus), Vesicular Stomatitis virus (VSV, Rhabdovirus) and Swine Vesicular Exanthema virus (SVEv, Calicivirus). Thus, clinical vesicular disease cases proven negative to those 4 viruses are considered "idiopathic vesicular disease".

The virus has been demonstrated by *in situ* hybridization in vesicular lesions of affected animals (Figure 1). Recently, the vesicular disease was experimentally reproduced using a contemporary isolate in animals of 9 weeks and gilts of 27 weeks of age (personal communication, Dr. Kelly Lager, USDA).

Association with ETNL, Brazil and USA

Recently (July 2015) Brazil has reported a novel clinical disease syndrome associated with SVA. Neonatal losses syndrome was reported affecting piglets of 0-7 days of age. The fatality rate was higher (40-80%) in 0-3 days old piglets and lower (40-80%) in 4-7 days old piglets. Litters older than a week did not seem to be affected clinically. Once disease was established, it had a relatively fast onset of a wasting syndrome progressing to mortality, and the herd recovered to baseline mortality levels within 4-10 days. It is important to highlight that most piglets (>80% had stomach full of milk/colostrum). Because of those characteristics, we proposed the term *epidemic transient neonatal mortality* (ETNL) (Vannucci, Linhares et al. 2015; Figure 2).

Extensive pathological evaluation of affected piglets from several herds in Brazil, and later in the Midwestern USA did not reveal any common/consistent gross or histopathological lesions that could explain the cause of piglet mortality. A consistent finding of herds developing ETNL was the detection of large amounts of Senecavirus A from multiple piglet tissues, including brain, blood and lymphoid tissues, indicating a widespread

infection (Linhares, Rademacher et al. 2015) (Figure 3). SVA has not been found in tissues from non-affected piglets.

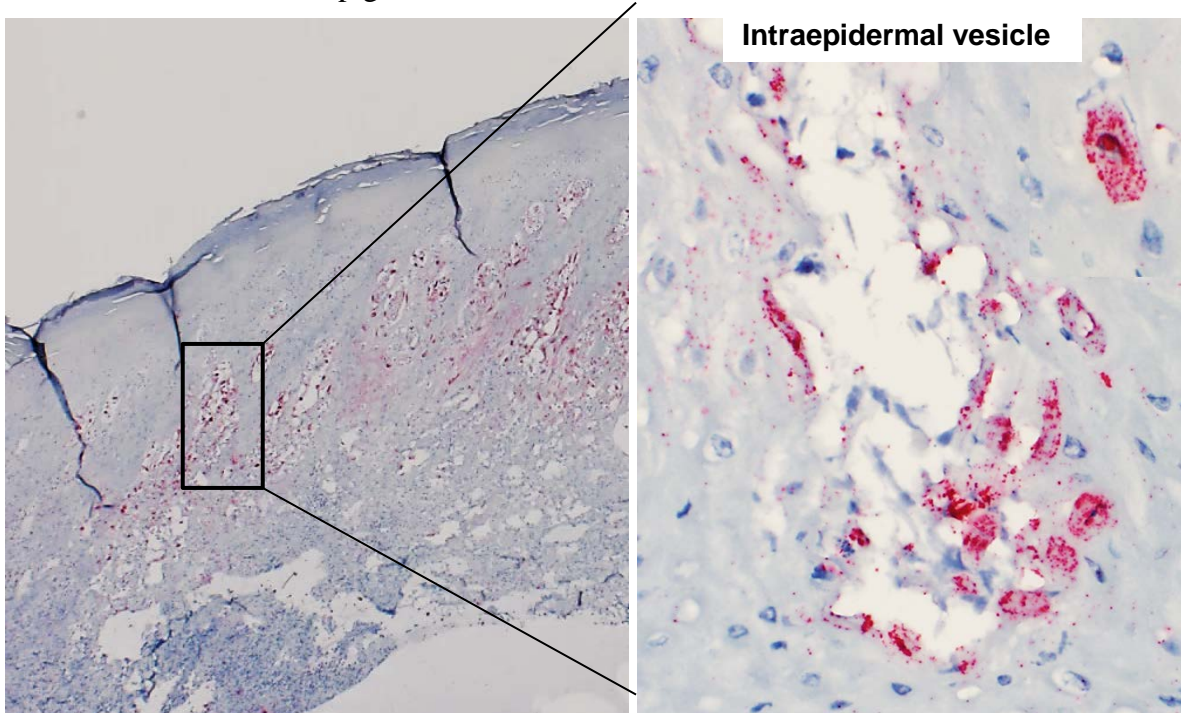


Figure 1. Skin biopsy of a vesicle from an affected pig. Presence of virus predominately in the stratum spinosum of the epidermis. Intraepidermal vesicle: virus replicating in keratinocytes.



Figure 2. Acute and transient characteristics of the epidemic transient neonatal mortality (ETNL). Left: typical appearance of an affected litter during an ETNL outbreak. Right: new litter from the same farrowing room 10 days after the peak of the mortality.

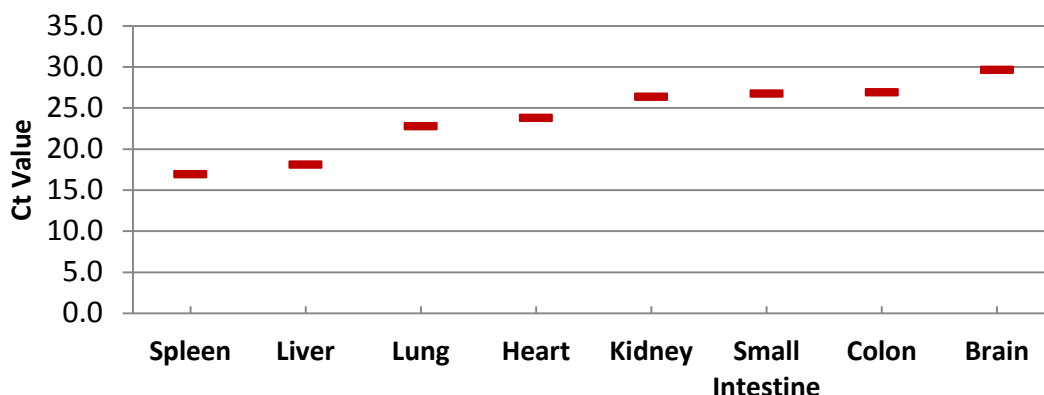


Figure 3. Distribution of the virus by quantitative PCR in tissues of ETNL-affected piglets.

Alongside with ETNL syndrome, some herds also reported idiopathic vesicular disease with moderate to mild lesions in the snout and/or foot (coronary bands, interdigital area or footpad). In other herds, no vesicular-like lesions were reported/seen, suggesting that SVA needs other contributing factors to establish disease (assuming that SVA causes disease). The IVD that accompanied ETNL also had a transient nature, with snout lesions healing within a few days and foot lesions healing within about 2 weeks.

Epidemiological remarks and implications

ETNL was disseminated quickly in Brazil, being clustered in time and space. In other words, when a specific herd reported the syndrome, neighbouring herds would also likely report ETNL, regardless of the production system, pig/person flow, genetic source or nutrition company. There were examples in Brazil and in USA of herds closed for >6 months (not introducing external gilts/boars) that developed ETNL. Altogether, these observations suggest that ETNL and/or IVD were transmitted also by indirect routes.

So far, the first herds that reported the outbreak (September 2014) have not (to our knowledge) reported a re-break. In other words, it seems that ETNL was a “one-time deal”, at least after a year. Considering that most herds have ~45% replacement rate, every ~2 years most sows have been replaced, indicating that ratio between susceptible : immune/resistant animals might change significantly. That could cause waves of ETNL cases every 1.5 to 2.0 years.

Assuming ETNL and IVD were both caused by SVA, this virus has a high transmission rate (regional level and herd level); it is highly immunogenic and has a long lasting (at least 1 year) immunity.

Recent molecular epidemiology work (Jianqiang et al. ASM science, accepted; Vannucci, Linhares et al 2015) showed that contemporary SVA isolates (USA and Brazil, ETNL and/or IVD cases) cluster separately from most historical SVA isolates, suggesting that SVA might have recently changed and somehow increased pathogenicity. Alternatively, the recent increase in clinical cases associated with SVA might be due to changes (increase) in transmission rate and/or environmental survival of SVA.

There is still need to understand how/where SVA “hides” between outbreaks and how it is transmitted between herds. In other words, can SVA remain infectious in feed ingredients? Is it airborne? Vector borne? Further research is needed to elucidate such questions.

Moving forward

A variety of work/research is being conducted to address needs such as a) develop/validate an ELISA for SVA, b) confirm SVA’s role on ETNL/IVD, c) understand molecular epidemiology of SVA in Brazil and USA, d) SVA-disinfection procedures.

Foreign Animal Disease (FAD) investigation must be triggered at every case where IVD is detected to rule out the other 4 vesicular diseases (including FMD).

ACKNOWLEDGEMENTS

Dr. Kelly Lager (USDA) Dr David Barcellos (UFRGS, Brazil), Iowa State University and University of Minnesota.

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ANTIMICROBIAL RESISTANCE – MYTHS AND REALITIES

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ABSTRACT

Antimicrobial resistance and its potential transmission from animals to man has become a major issue, both politically and scientifically, and is leading to greater controls, both in North America and Europe, on how we use antibiotics in agriculture and veterinary medicine. There is deep and sincere concern expressed by the medical profession about the worsening antimicrobial resistance situation in man and the potential that agricultural/veterinary use of antimicrobials is adding to their problem – to a large extent – the ‘myth’? Hence there is a call for a ‘One Health’ approach between human and animal use of antibiotics to try to combat the problem. However, much of the proposed legislation and controls on veterinary medicine is not based on factual assessments but assumptions, and the contribution that agricultural use is making on human antimicrobial resistance problems has not been quantified – the ‘reality’?

By analysis of the transmission of infections to man it can be shown that the direct transmission of infections and resistance from pigs to pig farmers/workers of such bacteria as methicillin-resistant *Staphylococcus aureus* (MRSA) and *Streptococcus suis* are relatively high at 83% and 21%, respectively. *Escherichia coli* transfer appeared to be lower at 4%.

Indirect transmission via meat appears to be a much smaller risk from pigs to the human population. *Campylobacter coli* transmission attribution from pigs to man is 0.3% of all campylobacter cases of food poisoning. Macrolide resistance tends to be higher in pigs but even so the resistance transmission rate in the EU is estimated at 0.00003% or 0.03 people/100,000 population. Similarly, the main salmonella infection, *S. Typhimurium*, found in pigs the transmission attribution of extended-spectrum beta lactamase (ESBL) resistance caused by the use of 3rd and 4th generation cephalosporins can be estimated at 0.00004% or 0.04 people/100,000 population. Recent attribution data of ESBLs transmitted from animals and food to man in the EU suggests that only 0.27% of resistant genes are identical to those found in man and therefore 99.73% are associated with human use of cephalosporins particularly in the hospital situation. Based on Swedish data the attribution of animal and food transmission (all species not just from pork) of ESBL resistance is 0.00022%/year or 0.22 people/100,000 population.

It appears likely that the attribution of antimicrobial resistance by indirect transmission to the general human population is overestimated and unlikely to have significant effects on resistance development in man. Both medical and veterinary doctors need to use antimicrobials responsibly and put infection control programmes in place to ensure that they remain effective for the future.

INTRODUCTION

Antimicrobial resistance and its potential transmission from animals to man has become a major issue, both politically and scientifically and is leading to greater controls, both in North America and Europe, on how we use antibiotics in agriculture and veterinary medicine. There is deep and sincere concern expressed by the medical profession about the worsening antimicrobial resistance situation in man and the potential that agricultural/veterinary use of antimicrobials is adding to their problem – to a large extent – **the ‘myth’?** Hence there is a call for a ‘One Health’ approach between human and animal use of antibiotics to try to combat the problem. However, much of the proposed legislation and controls on veterinary medicine is not based on factual assessments but assumptions, and the contribution that agricultural use is making on human antimicrobial resistance problems has not been quantified – **the ‘reality’?**

This paper attempts to quantify the significance of the use of antimicrobials in pigs on human antimicrobial resistance or enables it to be determined on a national basis.

OVERVIEW OF RESISTANCE DEVELOPMENT AND SPREAD

The use of antibiotics, especially when given by mouth, either in feed or in drinking water or tablets etc. may have a direct effect on the bacteria in the gut; i.e. kills them off if they are susceptible. They may be good bacteria or the bad **pathogenic bacteria** that you are trying to treat like *Escherichia coli* or *Brachyspira hyodysenteriae*. This exposure may select for organisms that are either **inherently resistant**, so they don’t die, then they multiply because of reduced competition or selects for resistant bacteria that have already **acquired resistance**. Bacteria can acquire resistance either by **mutations** of their DNA (remember they are often growing and multiplying at a very fast rate) and if this mutation is on chromosomes this leads to clonal spread as the bacteria multiply e.g. *Campylobacter coli* and fluoroquinolone resistance. Sometimes they acquire resistance via **plasmids**, which are passed from one cell to another by **conjugation** (almost sexually) and some bacteria like *E. coli* can spread plasmids very readily and these carry potentially **resistant genes** so are spread horizontally to possibly susceptible bacteria or potentially other bacterial species. Less common routes of transmission are by **transformation**; they pick up DNA left by other bacteria or by **transduction** where bacteriophages (viruses) inject the DNA. After treatment, the gut flora stabilises over time and often returns to what it was before. Some bacteria that have resistant genes or plasmids do not always survive or compete very well and naturally die off. Hopefully, the pig has developed immunity or is resistant to further infections.

Generally, in pig medicine we use a lot of oral antimicrobials via feed or drinking water; hence many of the bacteria we find in the gut carry a higher level of resistance. Resistance is often higher in young or weaned pigs where they have been treated but by the time they go for slaughter the resistance is less (Table 1). This is important to reduce potential indirect transmission of resistance via meat contamination.

We also use oral antibiotics to treat respiratory diseases such as *Mycoplasma hyopneumoniae* (enzootic pneumonia), *Actinobacillus pleuropneumoniae*, or systemic diseases like *Streptococcus suis* (strep meningitis) or *Haemophilus parasuis* (Glässer’s disease). Generally, resistance is lower against these infections but the gut flora is exposed

at the same time, hence tetracycline resistance is very high in *E. coli* (around 80%) but relatively low in *A. pleuropneumoniae* (24%).

Table 1. Comparison of antimicrobial resistance (%) in *E. coli* by age group in the UK (VMD, 2015).

Antimicrobial	Neonatal pig	Post-weaning	Adult
Ampicillin	49	61	35
Amoxicillin+ clavulanic acid	0	4	0
Cefpodoxime (3G)	0	1	0
Spectinomycin	51	52	24
Streptomycin	40	63	25
Neomycin*	5	2	12
Apramycin	3	37	6
Enrofloxacin	18	6	6
Tetracycline	77	82	59
Trimethoprim+ sulpha	49	64	29

Key: * not available UK

We also use oral antibiotics to treat respiratory diseases such as *Mycoplasma hyopneumoniae* (enzootic pneumonia), *Actinobacillus pleuropneumoniae*, or systemic diseases like *Streptococcus suis* (strep meningitis) or *Haemophilus parasuis* (Glässer's disease). Generally, resistance is lower against these infections but the gut flora is exposed at the same time, hence tetracycline resistance is very high in *E. coli* (around 80%) but relatively low in *A. pleuropneumoniae* (24%, Table 2).

Table 2. Antimicrobial resistance (%) in the EU to *A. pleuropneumoniae*, *S. suis* and *H. parasuis* (El Garch et al, 2015).

Antimicrobial	<i>A. pleuropneumoniae</i>	<i>S. suis</i>	<i>H. parasuis</i>
Amoxicillin	11	1	1
Amoxicillin+ clavulanic acid	0	1	0
Ceftiofur (3G)	1	2	0
Tulathromycin	0	67e	0
Tiamulin	0	85e	0
Tilmicosin	1	67	0
Florfenicol	1	0e	0
Enrofloxacin	1	1	0
Tetracycline	24	88	3
Trimethoprim+ sulpha	2	10	3

Key: e = estimate.

If low preventive levels or growth promotion levels are used this also increases the exposure of the gut flora, which may lead to greater resistance. So saying however, some bacteria acquire resistance quicker than others e.g. *E. coli* and some antibiotics develop resistance more slowly e.g. aminoglycosides such as neomycin and apramycin.

Some antibiotics given by injection are excreted primarily by the kidney (amoxycillin, ceftiofur) and thereby do not have such an impact on gut flora. Others, like enrofloxacin and tiamulin are metabolised and excreted mainly by the liver and bile duct directly into the gut and again can expose the gut flora to the drug. The former kidney excretors are good for kidney infections caused by *E. coli* and the liver excretors are often good for treating gut infections, like enrofloxacin and *E. coli* and tiamulin and *B. hyodysenteriae* (swine dysentery).

There is concern about **multiple resistance** development to pig pathogens by veterinarians and farmers e.g. we have multiple resistant *B. hyodysenteriae* in the EU, resistant to all licensed antimicrobials, which has made it necessary to depopulate herds. However, the main public concern about resistance in pigs in particular, is the potential transference of resistance, whether via **zoonotic bacteria**, which cause disease in man such as *Salmonella* or *Campylobacter* spp and make them more difficult to treat, or by **commensal bacteria**, such as *E. coli* and *Enterococcus* spp, which may transmit resistance via plasmids and genes to the human gut flora but may not cause disease directly in man. *Staphylococcus aureus* has become a recent concern, as it can colonise a pig's nose and may spread to man. In many countries in the EU and also N. America, many pig farms carry the methicillin resistant form (**MRSA**) in particular CC398. The bacterium can colonise the pig's nose and live there quite happily and may not cause disease, however it can colonise a human nose also but usually for a short time; it can cause disease in man but hospitals that screen patients are very worried about it coming into the wards and being spread to other patients or contaminating wounds of the carriers post surgery.

DIRECT SPREAD

Methicillin-resistant *Staphylococcus aureus* (MRSA)

The direct spread of MRSA from pigs to man has been a major issue. **Ninety percent** of MRSA CC398 human carriers and infected patients in Denmark (DANMAP, 2011) were associated with pig farming, either workers/farmers or veterinarians and their families. In Germany, colonisation was reported at **83% in pig farmers** and 4.3% of their families (Cuny et al, 2009). Additionally, 36% of pig veterinarians and 14% of slaughterhouse workers (Blaha et al, 2009) had nasal colonisation. The spread beyond to the general population was very limited. The methicillin-susceptible form (MSSA) has been around for a long time in humans but somehow got into pigs and it is postulated that the widespread use of 3rd generation cephalosporins in the 2000's probably **selected** for MRSA in piggeries. Methicillin or related compounds are not used in pig medicine but once it has the *mecA* gene it is resistant to all beta-lactam (penicillin-based) antibiotics. The pig associated MRSA is usually tetracycline resistant and has been found to have a chromium/zinc resistance *cra* gene associated with the *mecA* gene. Both tetracyclines and zinc oxide are widely used in many pig-producing countries but these are not **primary selectors** of methicillin resistance but may be **co-selectors** if they have the resistance genes as well as they may kill off susceptible bacteria, enhancing the survival of the resistant bacteria.

In Denmark, there is great concern about the spread of MRSA from pigs to man. The Danes (DVFA, 2014) identified that in 2013, 68% of finisher herds were MRSA positive and colonisation with MRSA CC398 in man was increasing rapidly to 643 cases (30.7%)

of overall MRSA colonised patients and infection and clinical disease associated with CC398 was 156 cases (**16.8%**) and of these, bacteraemias were **1.8%** and actual deaths were lower at approximately **0.8%** (Table 3). All mortalities had a number of serious underlying diseases.

Table 3. Epidemiology of direct contact infections from pigs to stockmen – MRSA Denmark.

Chain	Example	Contact population (Denmark)	General population (Denmark)
Organism	MRSA		
Source	Pig (68% herds)	20 million killed	
Host	Man	25,000 pig workers	5.5 million
Route	Inhalation dust		
Susceptibility of host	High	High	High
Colonisation	83%	14,100 (56.4%)	0.26%
Infection	16.8%	156 (1.1%)	0.0028%
Disease incidence	16.8%	156 (1.1%)	0.0028%
Resistance transfer (%)	100	100	100
Treatment failure	0.8%	1.25 (0.8%)	0.000023%
incidence due to resistance			
Mortality incidence	0.8%	1.25 (0.8%)	0.000023%

The potential direct spread of the pig MRSA to stockmen can be very high and therefore **methicillin resistance** spread to stockmen is also high. By comparison, the spread amongst the general Danish population is incredibly low and potential infection rate is **0.0028%** in comparison with **1.1%** in stockmen.

Streptococcus suis

Barlow et al (2003) in the UK reported that **21% of pig stockmen** were seropositive to *S. suis* type 2; there were approximately two clinical cases/year over a 20 year period and approximately 12.5% of cases died from the infection. One death was in a case who was asplenic (immunocompromised). Approximately, 20-30% of UK pig farms are affected by *S. suis* infections. Interestingly, almost all of the isolates in the UK cases were penicillin susceptible, the main antibiotic used for treatment, so penicillin resistance transfer *per se* was not the issue and could be considered as effectively zero.

Direct transmission of *S. suis* to pig farm workers can be considered high at 21% causing seroconversion but infection transmission amongst the general public is low at 0.0032% and penicillin resistance transfer is zero (Table 4).

Escherichia coli

In contrast, Nijsten et al. (1996) in the Netherlands found that the antibiotic resistance of *E. coli* in faecal samples of pig farmers was significantly lower than samples obtained from pigs. The resistance patterns of only **4% of farmer *E. coli*** were the same as pigs from the same farm. DeBeen et al. (2014) did show that direct transmission of *E. coli* carrying

plasmids and extended-spectrum beta lactamase (ESBL) resistance genes could be transmitted from pigs to farmers.

Direct spread of bacteria from pigs to farmers can be considered high and as a consequence, the potential risk of the direct spread of antimicrobial resistance can also be considered high.

Table 4. Epidemiology of direct contact infections from pigs to stockmen – *S. suis* UK.

Chain	Example	Contact population (UK)	General population (UK)
Organism	<i>S. suis</i>		
Source	Pig	10 million slaughtered	
Host	Man	10,000 pig workers	65 million people
Route	Direct		
Susceptibility of host	Low - moderate	Low - moderate	Low - moderate
Colonisation	21%	2,100	0.0032%
Infection (seroconversion)	21%	2,100	0.0032%
Disease incidence	0.02%	2 (0.048%)	0.000003%
Resistance transfer (%)	0	0	0
Treatment failure	0	0	0
incidence due to resistance			
Mortality incidence	12.5%	0.25 (0.095%)	0.0000003%

INDIRECT SPREAD

Campylobacter coli

Campylobacter spp are currently the most frequently transmitted enteric infections transmitted from animals to man, mainly by contaminated food and the environment (EFSA/ECDC, 2014a). *Campylobacter jejuni* infections are the most common in man accounting for approximately **94.4%** and *C. coli* for approximately **5.6%** (Mughini Gras et al., 2012) in a Dutch case control study. Chickens have a similar proportion of *Campylobacter* species to humans and cattle are predominantly *C. jejuni* too. Pigs however, carry predominantly *C. coli* and Burch (2002) concluded that using macrolide (erythromycin) resistance as a marker, pig *C. coli* were unlikely to contribute significantly to human *C. coli* infections. Carcass contamination of pork with *Campylobacter* spp is also very low at 0.6% but chicken carcasses are high at 31% (EFSA, 2011). Mughini Gras et al. (2012) looked at a combined case control and genetic source attribution analysis for both *C. jejuni* and *C. coli* in the Netherlands, using multi-locus sequence typing (MLST). Overall, they attributed cases, 66.2% to chicken, cattle 20.7%, sheep 2.5%, **pigs only 0.3%** and environment 10.1%.

The susceptibility of *C. jejuni* to the fluoroquinolone, ciprofloxacin, is relatively low but the susceptibility to macrolides (erythromycin) is comparatively high (EFSA/ECDC, 2014b, Table 5). In contrast the susceptibility of ciprofloxacin to porcine *C. coli* is higher but erythromycin lower.

Therefore, based on the Mughini Gras et al (2012) attribution, a likely EU assessment (EFSA/ECDC, 2014b) of resistance attribution to humans of the 214,268 reported cases from *Campylobacter* spp infections can be made for pigs and poultry for macrolides (Table 6).

Table 5. Resistance* (%) of *Campylobacter* spp to antimicrobials in the EU.

Species	Ciprofloxacin	Erythromycin	Gentamicin	Tetracycline
<i>C. jejuni</i>				
Human (14MS)	54.1	1.4	0.2	28.3
Chicken (10MS)	44.1	0.4	0.7	34.1
Chicken meat (8MS)	59.5	1.8	0.7	47.5
Cattle (5MS)	32.9	0.6	0.2	43.5
<i>C. coli</i>				
Human (14MS)	42	15.1	1.8	49.7
Chicken (6MS)	78.4	11.2	4.1	73.1
Chicken meat (6MS)	82.7	16.5	1.7	57.3
Pigs (5MS)	32	23.9	2.9	76.8

(EFSA/ECDC, 2014b) *Human data used clinical breakpoints, whereas animal data used epidemiological cut-off breakpoints, so not directly comparable. MS = Member States

Table 6. Comparison of *Campylobacter* spp transmission by pigs and chickens to humans and macrolide resistance in the EU.

Chain	Example	Population (EU)	Example	Population (EU)
Organism	<i>Campylobacter</i>		<i>Campylobacter</i>	
Source	Pig	250 million	Chicken	6.7 billion
Host	Man	500 million	Man	500 million
Route	Meat	Meat	Meat	Meat
Susceptibility of host	High	High	High	High
Colonisation	Low	Low (5.6% Cc)	High	High (94.4% Cj)
Infection	0.3%	214,268* cases	66.2%	214,268* cases
Disease incidence	0.3%	643 cases (0.00013%)	66.2%	141,845 cases (0.028%)
Resistance transfer	23.9% (Macro)	154 (0.00003%)	1.8% (Macro)	2553 (0.0005%)
Treatment failure	ND	ND	ND	ND
incidence due to resistance				
Mortality case incidence	0.03%	0.2 cases (0.00000004%)	0.03%	28.2 cases (0.000006%)

Key: Macro = Macrolide *Reported cases of campylobacter in man; Cc = *C. coli*; Cj = *C. jejuni*; ND = No data.

Macrolide resistance is transmitted by pigs to man at a very low rate of **0.00003% or 0.03 people /100,000 population** and the incidence or potential macrolide resistance transfer from chickens is also low **0.0005% or 0.5 people/100,000 population**. This is in accord

with the European Medicines Agency's categorisation of macrolides (EMA, 2014) as a lower risk family of antimicrobials in their Category 1, in contrast to the World Health Organisation's (WHO, 2011) assessment of being a Highly Critically Important Antibiotic (HCIA).

***Salmonella* spp**

The incidence of reported salmonella cases has been steadily falling in the EU since 2004 when it was 195,947 cases (EFSA/ECDC, 2010) until 2012 when it was 91,034 cases (EFSA/ECDC, 2014a), a 54% fall, following the introduction of vaccine and hygiene measures in poultry flocks. The main effect has been a reduction of the incidence of *S. enterica* Enteritidis, which contaminated meat and eggs but *S. Typhimurium* cases, the main pig isolate, have stayed much the same (Table 7).

In the EU, in contrast, the main human salmonella serovars were **41.3% *S. Enteritidis*** and **29.3% *S. Typhimurium* and monophasics** (EFSA/ECDC, 2014a). Pigs are commonly associated with *S. Typhimurium* but phage typing of GB isolates tells a different story that possibly only one third (**9.8%**) are pig associated (AHVLA, 2014) and therefore **51.1%** are chicken associated (both *S. Enteritidis* and *S. Typhimurium*).

The antimicrobial resistance patterns for *S. Typhimurium* have been reported in EFSA/ECDC (2014b, Table 8).

Table 7. Isolation of the most common salmonella serovars in humans and animals (%) in GB (AHVLA, 2014).

Serovars	Human	Pig	Chicken	Cattle
<i>S. Enteritidis</i>	27.7	-	-	-
<i>S. Typhimurium</i>	11.0	33.1	-	5.0
Monophasic <i>S. Typhimurium</i>	10.1	43.3	-	3.5
<i>S. Infantis</i>	3.0	-	-	-
<i>S. Newport</i>	2.6	-	-	-
<i>S. Virchow</i>	2.3	-	-	-
<i>S. Stanley</i>	1.8	-	-	-
<i>S. Kentucky</i>	1.6	-	-	-
<i>S. Paratyphi</i> (Java)	1.5	-	-	-
Others	38.2	23.6	100	-

Table 8. A comparison of antimicrobial resistance (%) to human and animal *S. Typhimurium* isolates (EFSA/ECDC, 2014b).

Antimicrobial	Human (19MS)*	Pig (5MS)**	Chicken (5MS)**	Cattle (7MS)**
Ampicillin	66.6	76.7	39.5	34.5
Cefotaxime (3G)	0.9	2.3	4.0	0.4
Ciprofloxacin	2.2	7.5	17.7	9.1
Gentamicin	3.0	3.7	1.6	1.1

Key: MS = Member States; 3G = 3rd generation cephalosporin; *Clinical breakpoint; **Epidemiological cut-off value.

The estimation of transfer of cefotaxime (3G) (ESBL) resistance from pigs and chickens to man via *Salmonella* spp infections is summarised in Table 9.

Table 9. Comparison of *Salmonella* spp transmission by pigs and chickens to humans and cefotaxime 3G (ESBL) resistance.

Chain	Example	Population (EU)	Example	Population (EU)
Organism	<i>Salmonella</i> spp		<i>Salmonella</i> spp	
Source	Pig	250 million	Chicken	6.7 billion
Host	Man	500 million	Man	500 million
Route	Meat	Meat	Meat	Meat
Susceptibility of host	High	High	High	High
Colonisation	Low	Low	High	High
Infection	9.8%	91,034* cases	51.1%	91,034* cases
Disease incidence	9.8%	8,921 (0.0018%)	51.1%	46,518 cases (0.0093%)
Resistance transfer	2.3% (cefotaxime)	205 (0.00004%)	4% (cefotaxime)	1,860 (0.00037%)
Treatment failure incidence due to resistance	ND	ND	ND	ND
Mortality case incidence	0.14%	12.4 cases (0.0000025%)	0.14%	70 cases (0.000014%)

Key: ND = No data; *Reported cases of salmonella in man (EFSA/ECDC, 2014a).

The estimated transmission rate of cefotaxime (3G) resistance via *Salmonella* spp from pigs to man is **0.00004% or 0.04people/100,000 population**. For chickens the transmission rate is higher at **0.00037% or 0.37people/100,000 population**. On this basis ESBL resistance transmission can be considered very small even for chickens.

Escherichia coli

There have been a number of reports in the EU looking genetically at ESBL resistance genes found in urinary tract infections and blood-borne infections in man and comparing them from ESBLs found in animals and food (Wu et al, 2013, SVARM, 2015; DANMAP, 2015; Burch, 2015).

These results demonstrated that **2/747 (0.27%) ESBL resistant genes** were identical to genes found in animals and food and that **745/747 (99.73%) were attributable to human** use of 3rd and 4th generation cephalosporins in man (Table 10). Surprisingly, the Danes concluded in their report that “consumption of meat may currently be considered an insignificant source for the human infections” (DANMAP, 2015). Using the SVARM (2015) data the attribution rate of ESBLs from animals to human infections was 1/379 (0.26%), which represents on a transmission rate basis that the number of clinical cases potentially caused by ESBL containing *E. coli* from food/farm animals = 21.2/8,161 cases or an infection rate of **0.00022%/year** on a 9.5 million population basis. This represents **0.22 people/100,000 population** out of 85people/100,000 population which would normally get infected, i.e. an extremely low infection rate.

Table 10. Combined results ESBL resistance gene attribution from animals and food and those in clinical infections in man (Wu et al, 2013, SWARM, 2015; DANMAP, 2015).

Reference	Member States involved	No. human ESBL genes tested	No. of animal ESBL genes identical	Percentage animal/human ESBL genes identical
Wu and others, 2013	UK	127	0	
	Netherlands			
	Germany			0
SVARM, 2015	Sweden	379	1	0.26
DANMAP, 2015	Denmark	241	1	0.41
Total	5	747	2	0.27 (SD \pm 0.21)

RISK ASSESSMENT SUMMARY

A comparison of risk assessments for transfer of infectious agents and antibiotic resistance transfer from pigs to man are summarised in Table 11.

Table 11. Comparison of risk assessments for transfer of infectious agents and antibiotic resistance transfer directly from pigs to farmers or indirectly from meat to man.

Direct transmission to farmers			
	Colonisation (%)	Disease (%)	Resistance (%)
MRSA	83	16.8	100
<i>S. suis</i>	21	0.02	0
<i>E. coli</i>	4	0	4
Indirect transmission to population			
<i>Campylobacter</i> spp	0.00013	0.00013	0.00003 (macrolide)
<i>Salmonella</i> spp	0.0018	0.0018	0.00004 (ESBL)
<i>E. coli</i>	Low	Low	0.00022 (ESBL)

In comparison, direct transmission from pig to farmer is potentially very high, depending on the organism and the infection on the farm. Indirect transmission from meat to man is apparently very low.

CONCLUSIONS

The direct transmission of infectious agents from pigs to man, working and caring for the animals, is unfortunately very high. It also depends on which bacteria are present on the farm. The transmission of MRSA to farmers and veterinarians appears to be very high. Fortunately, colonisation in man is not long lived and there is a low incidence of infection and disease with it. Similarly, for *S. suis*, the transmission probably in the air and dust is also very high and the colonisation and seroconversion is also high but the incidence of disease is low. *Escherichia coli* probably can be easily transmitted by faecal and dust

contact to the farmer and may be ingested. Fortunately, colonisation is comparatively low and infections are low but the spread of plasmids and resistance genes does occur.

Indirect transmission via pig meat and its products would appear to be very low. Only 0.3% of human *Campylobacter* spp infections are attributed to pigs. Macrolide resistance may be a little higher than say in poultry but overall the infection rate and resistance transmission rate is very low. Salmonella in man is changing in the EU with an over 50% reduction, mainly of the chicken infection *S. Enteritidis*. Sero-typing of *S. Typhimurium*, the main pig strain, shows that both poultry and cattle contribute also and it is not just pigs that carry it. ESBL resistance is not high so actually the transmission rate of this important resistance is low. Recent data regarding ESBL resistance transmission by *E. coli* also demonstrates a very low transmission rate from food to man and causing infections in man. There is a different epidemiology of resistance transmission spreading in man because of the high usage of cephalosporins in man and the transmission of infectious agents and their resistance genes particularly in hospitals (Overdevest, et al, 2011).

Antibiotics must be used responsibly in pigs and the future legislation is likely to reduce their use by banning growth promotion and moving them under veterinary prescription. In the EU we are going further by banning prophylactic use and restricting in-feed medication. The ‘myth’ that antibiotic use in pigs causes a huge amount of resistance in man does not stand up to close scrutiny and hopefully the ‘reality’ will be taken on board by legislators to prevent over-restriction of the use of antibiotics in veterinary medicine and endangering the health, welfare and productivity of pig production.

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CHANGING BUSINESS STRUCTURE OF THE NORTH AMERICAN HOG INDUSTRY

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INTRODUCTION

The intent of this note is to highlight current structure of the North American pig industry and offer one perspective on drivers of change and their possible impacts over the next several years. We are living in a time of accelerating discovery and innovation accompanying powerful demographic and economic change on a global scale. Clearly, the dramatic volatility experienced by the North American pig industry over the past decade affected current structure. Experience over the past decade also suggests how the industry may be affected by change in the future. This note concludes with suggested targets for analysis and information to support future profits.

The perspective here is based on the idea that the industry is driven by firm or farm level realized profit and by perceived expected profit and risk. A perspective is offered by looking back and forward at drivers of change and their impacts on profit and risk at various points in the supply chain. Drivers and their implications for structure are discussed in terms of their effects on supply and demand through time. Demand drivers include familiar (and some less familiar) views on global and domestic growth: in population, age demographics, income, middle class income; all filtered by religion, food traditions, and emerging tastes and preferences. Supply drivers are discussed in the terms of Total Factor Productivity (TFP) and touch on major technology changes affecting genetics, feed, health, environment, labour, logistics, and processing. Supply and demand interact in markets where drivers include policy and trade issues as well as the effects of seemingly unrelated markets.

LOOKING BACK AND STRUCTURE NOW

Structure of the pig production sector has continued to evolve over the past decade although without the radical re-organization seen in earlier decades. Combined US and Canadian pig inventory in December 2015 was 81.6 million including 7.24 million head kept for breeding (USDA, NASS). This compares to the December 2007 inventory of 79.1 million pigs including 7.71 million kept for breeding. The US inventory in December 2015 was the largest on record although only 4% larger than the 65.5 million recorded in September 2007. US swine inventory exceeded 60 million head in 1900 and in 1980. The similarity of inventories in 2007 and 2015 conceals tremendous economic turmoil over the past decade that finally drove US inventory below 62 million in 2013/2014.

Productivity of the North American swine herd continues to grow. For example, pigs saved per sow farrowed rose from 9.16 in 2006 to 10.3 in 2015 (USDA, NASS). Annual sows farrowed per breeding animal in inventory rose very slightly from 1.956 in 2006 to 1.964 in 2015. US annual pork production rose from 22 billion pounds carcass weight in 2007 to 24.5 billion pounds in 2015. USDA does not provide comparable data on feed conversion. Anecdotal data suggest that feed conversion remains around 2.4 to 2.5 pounds

feed per pound liveweight gain in the wean-to-finish phase despite rising market weights. Darku et al. (2016) analyzed Total Factor Productivity growth in Canadian agriculture.

Ownership and coordination of the North American pig industry continue to evolve. Successful Farming magazine's Pork Powerhouses annual article (Freese, 2006, 2015) provides a snapshot of sow ownership by the largest firms in the US and Canada. In 2015, the largest 20 US producers owned 3.28 million sows or about 55% of the US sow herd. In 2006, the largest 20 producers owned 2.42 million sows in the US or about 40% of the US breeding herd. The lists reveal significant levels of sales (e.g. WH buys Smithfield), mergers, acquisitions, bankruptcies, expansion, and contraction; driven in part by extended periods of financial losses (September 2007 to January 2010 and September 2012 to May 2013) due to sharp reductions in grain supply. The lists of the 5 largest pig producers in Canada show their total sow inventory dropped from 284,000 in 2006 to 257,000 in 2015 with contractions, expansions, entries, and exits evident.

A primary driver for structure of the pig industry over the past few decades has been coordination with meat packing, processing, and pork marketing. Several imbedded motives are discussed: reducing the cost of logistics; standardizing the size, type, and quality of pigs processed; securing shackle-space or pig supply; creating specialized quality control and trace-back for targeted customers; reducing cash-flow volatility by integrating across supply chain links; et cetera. By 2009, Grimes and Plain reported that about 8% of US slaughter hogs were sold at 'negotiated' prices while the rest were sold under a prior agreement or were owned by the packer. The Pork Powerhouses list in 2015 reveals several groups of producers collaborating to supply a packing plant, in addition to the large packers integrated back to pig production. US 2014 market hog slaughter capacity was estimated at 452,445 head per day (pork.org) in 2015. About 90 percent of that capacity is owned by 30 companies and the largest company owns just over a quarter of the capacity. Two new packing plants will add 20,000 head per day to that total soon. Packing capacity limits hog production and vice versa; nationally and regionally. In a highly coordinated system designed to operate all facilities near their capacity, changing capacity is constrained in the short run; and real growth takes years of planning and implementation. As we have seen, loss of substantial capacity at one point in the chain causes damage to the connecting 'links' when there is no excess capacity in the chain.

Policy and trade are major drivers of structural change in the North American pig industry. The Renewable Fuel Standards, COOL, import bans, economic growth and recession in trading partner countries, and exchange rates have all affected structure in the past decade.

DRIVERS OF CHANGE AND FUTURE STRUCTURE

Accelerating rates of change in the world are likely to drive change in the pig industry. Here are a few such trends and a perspective on how they might affect the pig industry.

We are experiencing a radical transition in the global energy paradigm. The emergence of 'fracking' as a common oil and gas extraction technology is having a dramatic effect on energy prices as we have seen. Slightly less obvious is the effect it is having on the US balance of trade: where the US was importing 60% of its oil a decade ago (and exporting US dollars), now it has legalized oil exports and may become a net exporter in the near future. With US production of liquid fuels alone at about 290 billion gallons per year, the change in trade balance and prices is significant. The resulting fall in oil and gas prices is

highly correlated with the strengthening of the US dollar, and perhaps the decline of the Canadian dollar (as an oil and gas exporter). This current oil and gas paradigm may remain in effect for 20 years based on past oil cycles and the reported proven reserves.

Effects of this change on the structure of the pork industry may include increased profits for exporters from weaker currency countries and decreased profits for exporters in strong currency countries. Consumers in strong currency countries find domestic and especially imported goods and services less expensive and buy more; consumers in weak currency countries may find domestic and especially imported goods and services more expensive and buy less. Exchange rates have differing effects on prices of different goods and services. “Stickiness” of cross-border prices affects impacts of exchange rate movements. Stickiness is affected by policy, transactions costs, transactions time delays, etc. Even traded goods may experience significant changes in cross-border prices. Structural changes may be linked to national policies that address the new paradigm through monetary policy and interest rates (trade flows are only part of exchange rate determination; capital flows are also very significant and are influenced by relative interest rates, inflation rates, expectations and uncertainties, etc.). A question for pig producers is do exchange rates increase pig prices in Canada more than they increase prices of inputs such as feed, labour, loan payments, and taxes. To what extent have the difficulties of the Canadian packing sector been created by a weak US dollar over the past several years and does this weaker Loonie change the pro forma for new investments?

Demographics and economic trends are likely to increasingly drive demand and affect supply and price of labour. The populations of the developed countries of the world are aging and especially those with low immigration rates are expected to experience increasing proportions of their population being over 65 while the proportion of working aged people declines. We elder folks may eat differently than when we were younger. Elsewhere, global population is expected to increase by 30% over the next few decades with most of the growth occurring in Asia and Africa; where the rapidly growing populations are very young; and increasingly urban. Perhaps less recognized, is that the global middle class is growing at a much greater rate than the population as a whole; a World Bank study predicted 167% growth in the middle class between 2005 and 2030. Middle class consumers are driving global demand growth including demand for pork. Growth of the middle class may continue long after the population growth slows down. Demographic trends may impact national policy regarding immigration, minimum wages, food security / welfare programs, support for the elderly, taxes and other transfers.

Just a few areas of technological change are mentioned here but their effects may be profound. Robotics and automation are gradually becoming more mainstream. Multiple effects of this technology may include lower cost, less labour intensive, and more consistent manufacturing and processing systems. Apparently we are not there yet; at least Mercedes recently announced that they were replacing some robots with people because the robots couldn't handle the multiple choices associated with their assembly. Another effect of robotics and automation was raised at the Emerging Issues Forum in Raleigh a few weeks ago: one speaker there suggested that 50 % of North Carolina manufacturing jobs may disappear in a few decades due to automation. It may be that automation further lowers cost of pork processing, adds value to cuts, increases derived demand for pigs, and reduces competition for some types of labour. There may be increased demand for labour to operate and maintain and program machines.

A very rapid transition is occurring in the use of monitors, wireless communications, big data, and analytics. Low cost, high speed sensing, data transfer, storage, analysis, and remotely driven control are affecting us in multiple ways: from precision agriculture to the 'fit-bit'. The pig industry has exposure to electronic monitors for sows and various devices to control equipment and send notifications. The potential to more precisely, and inexpensively manage individual animals in terms of diet, health, reproduction, and marketing could extend trends in improving pig and worker environment, feed efficiency, reproductive productivity, liveability, and marketing to grid optimization.

Finally, gene editing has emerged as a new tool to accelerate genetic improvement in organisms including pigs. Accelerated genetic improvement may reduce the cost of feed, create more efficient and robust pigs with ideal meat characteristics, reduce the need for medications, reduce the risk of disease, and generally reduce the cost of raising pigs and pork. The social stigma around GMOs may evolve into specific standards for the absence of specific proteins and compounds as the fear of 'Franken-food' declines. The use of new information systems and systems biology can now provide real-time feedback to swine genetics providers on the performance of individuals and their genotype in specific biotic and abiotic environments.

CONCLUSIONS

Managers and investors need validated info on new technology now more than ever. They also need transparent supply chain economic analysis of the impacts of emerging technological innovation, demand shifts, demographic changes, seemingly unrelated market effects, and policy changes. Different changes have different likely effects on structure. There appear to be large opportunities for further precision management, another genetic (r)evolution, and entrepreneurial innovation. Time allows presentation of only a few ideas today. The need for educational conferences like the LSC is stronger than ever. Pig industry research and educational institutions are and will be investments that generate huge ROIs for producers and allied industry.

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Day 2: Wean to Finish – Workshop Sessions

BEHIND THE NUMBERS OF FINISHING BARN MANAGEMENT

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Like most everything else about running a successful business, the key to success in a finishing operation is attention to detail.

Nurseries and finishers are especially easy to overlook as automatic feeding systems, water, automated ventilation and security systems give us a false sense of security.

The pigs have feed and water and the air is fine, so everything must be okay.

This is especially true if you employ Contract Growers.

Contract Growers are mostly arable (crop) farmers who build barns for a variety of reasons. They want the manure, it is a good investment, they want something for their kids to do on the farm, they want to expand their business but farm land is too expensive, etc. When was the last time you heard a Contract Grower say “I got into contracting because I like working with pigs?”

For this reason, when times get busy in the field or other parts of the business, the first thing that tends to get neglected is the pig barn.

As Producers, we have to understand and monitor this ourselves to make sure that all the little things that need to be done in the finishers to make them as efficient as possible are being done all the time.

We believe a Fieldsman can oversee about 60,000 spaces. This number allows him or her to pay adequate attention to detail to make sure everything runs as smoothly as it can.

That doesn't mean Fieldsmen cannot do other things. If you are not big enough to have 60,000 spaces, then maybe the Fieldsman has other responsibilities as well.

We must never forget that more money is made and lost in the growing stage than anywhere else in production. An increase in PWM of 5% might cost you under \$2.00 per pig, but an increase in FCR of 5% would cost you over \$4.00 per pig. I could argue you are more at risk of your FCR increasing by 5% than your PWM increasing 5%.

I would say the four key things to successful finishing are the following:

- Develop checklists for both the barn operator and the Fieldsman. Make sure as they go through the barn and check off things on the checklist, that they are recorded. You can then monitor repeatable incidents with individual growers and develop a profile of things that you need to pay special attention to with individuals.
- Keep a database of everything that goes on. Every system is different and different things will work in some systems versus others. If you monitor and record all the little things that influence your production and profitability, then you will be able to make good decisions on how to manage your nurseries and finishers (“You can't manage what you can't measure” – Frank Aherne).

- Lastly you need to know how you are doing against the rest of the industry. Develop a benchmarking group that you are comfortable with and trust the numbers. It is very easy to fudge numbers and people do it with the best of intentions. For that reason, it is better to have a third party that you all trust to put the numbers together (SMS do a great job of this).
- Health and biosecurity. This often gets overlooked in finishing and people tromp in and out without thinking. “I don’t have any other pigs, so there is no risk.” Well, did you go to the local elevator today to deliver grain? Was there someone in there before you who had PED on their farm? Eliminate risk by working with your veterinarian to develop effective biosecurity measures.

Our industry is changing fast. Genetics, management techniques, nutrition and outside pressures all have an impact on our businesses. Management of our barns is an ever changing challenge. We need to make sure we are always up to speed with where the industry is going and the latest ideas and techniques.

We need to be ready to make changes if and when they make sense. We can only do this if we have established and monitored protocols and we know what the cost and effect of making changes will have on our production and business.

WEAN TO FINISH PRODUCTION WITHIN SCHWARTZ FARMS

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ABSTRACT

Schwartz Farms has been a leader in swine production for many years in southern MN and northern IA. Our mission statement is “Producing quality pork and creating opportunities for rural communities.” Our core values are integrity, respect, excellence, innovation and adaptability. Schwartz Farms has been involved in wean to finish production for nearly 20 years now. This manuscript will overview where Schwartz farms started and where it is at today in wean to finish production and highlight the production practices that have made Schwartz Farms successful over the years.

HISTORY

Schwartz Farms was started by brothers Joe and John Schwartz in the 1980s. The crop side of the company, consisting of primarily corn and soybeans, has grown over the years along with the swine side. The start of swine operations consisted of purchasing small groups of feeder pigs. In the 1990s Joe and John obtained farrowing units which were contractor owned and operated consisting of about 2000 sows across several farms. Market sales consisted of just a few market loads per week. In 1998 the distressed hog markets offered expansion opportunities. The expansion started with leasing a 5400 head sow farm along with picking up additional land acquisitions. Schwartz Farms continued to grow moderately over the years building, expanding and purchasing sow herds most recently picking up sow herds in northeastern NE along with contract wean to finish barns. In 2005 SFI also started building company owned and operated wean to finish sites modifying and improving the design every year along the way, while at the same time seeking out good partners in production to house and care for the herd in contractor wean to finish and finishing facilities.

Schwartz Farms Today

Today the SFI sow herd is made up of 58,000 sows on 14 farrowing farms. 12 farms are company owned, 1 farm is leased and another is an independent contractor. 7 sites are in southern MN, 6 are in NE which were acquired at the end of 2014, and another resides in eastern SD. The sow farms range in size from 1500 to 6000 sows per site. Currently SFI has around 100,000 company owned and operated wean to finish sites, 128,000 company operated sites, and 465,700 spaces with independent farm families for a total of 694,000 wean to finish and finishing spaces. SFI employs 350 full time employees including a crew of 10+ in its own repair and maintenance division, 125 part time employees and 200 independent farm families. 7 major toll mills manufacture feed needing to procure 13 million bushels of corn and 80,000 ton of soy annually. Contact haulers transport market and feeder pigs while vet services, boar semen, and replacement stock is all out-sourced as well. The SFI entire operating area consists of Minnesota, Iowa, South Dakota, and

Nebraska. The main office is near Sleepy Eye, MN with smaller offices and warehouses in St. James, Luverne, and Leigh NE. SFI also recently built its own wash and bake facility in Springfield, MN which is for sow farm transportation trucks and trailers only. In 2008 SFI marketed approximately 609,000 pigs and in 2015 was nearly 1.3 million marketed to several different packers.

SOW FARM HEALTH AND IMPROVEMENTS

Sow herd health is variable. Some farms are PRRS and myco negative. Some are PRRS positive and myco negative while others are PRRS negative and mycoplasma positive. Flu virus will also infiltrate sow herds from time to time along with some PED and DCV breaks within the last 2 ½ years. SFI continues to strive towards PRRS and mycoplasma negative herds through mycoplasma eradication programs, PRRS cleanup programs, filtration of a majority of sow herds and increased biosecurity with the addition of our own wash and bake facility in which all transport equipment used to haul wean pigs, replacement gilts or cull sows is directed to immediately after delivery for wash and bake to 160 degrees for 10 minutes. Filtration has reduced PRRS break rates as much as 7 fold (1 break in 6 years under filtration compared to 6 breaks in 5 years) at the most successful farm. There has been 4 fold reductions on other farms. Other improvements have been in sow productivity over the past 3 or 4 years with continuous improvement from genetic suppliers in total barn, litter wean weights, etc., and with the addition of 24 hour care at the sow farm level we have seen reduced stillbirth rates and prewean mortality with the most immediate and dramatic improvement in stillbirth reduction.

PIG FLOW

Most sow farms are flowed separately and kept separate for the life of those pigs. Larger farms in particular flow on their own to wean to finish sites with some smaller farms flowed together when health matches up, and 1 small farm is batch farrowed. This model has been followed for many years trying not to create more instability with differing and ever changing health statuses. It does create challenges with slower fills but with trial and error over the years, we still feel that commingling sow farms for us can create greater risks than keeping sources separated. SFI does have some conventional nurseries, but the large majority of wean pigs are flowed into wean to finish sites of various sizes most commonly ranging from 2400 to 3300 head sites. Wean to finish sites are double stocked to around twice the amount of the normal finishing stocking density for a period of around 7 weeks at which time the overstock is hauled out to standard finishing sites with the remaining pigs being split down to be finished out at the original site. Some wean to finish sites will be dumped out at the end of the nursery phase and refilled if needed. Whether doing this or finishing groups out, it is almost always all in all out, providing breaks of down time in between new groups starting.

BARN DESIGN AND SET UP

Current Schwartz Farms wean to finish barn requirements include a tunnel ventilated barn with an office designed with a biosecurity bench before a shower through system. The office area also highlights a water softener, hot water heater, utility sink, mini fridge, washer and dryer, desk work area etc. The barns also feature an Agri Alert alarm system,

on site auto start generator, several back up thermostats and curtain drops. We also have enclosed attached load chutes with bumper pads and dock seals. The building itself requires insulated concrete stem walls and a Schwartz approved pen layout consisting primarily of a small pen layout with wean through finish gating and poly alley gates. Feeders and drinkers consist of a custom built SDI brand wet dry shelf feeder or other brand equivalent that meets our specs. Approved double nipple drinker cups are also added to wean to finish barns with water cup dripper system. We are currently using the Expert or Edge controllers with actuated inlets operated by curtain machines tied into the ventilation controllers. Gas brooder heaters are the last primary item with one heater over every divider gate which will provide zone heat for approximately 150 weaned pigs. Finally, prior to wean pig delivery, 4x8 foot comfort boards, 1 per pen or 2 per brooder, are added to the pens for creep feeding and zone heat laying area.

WEAN PIG START UP

The most important part of wean to finish production is the initial start after weaning. Weaned pigs are delivered by each farm's own designated truck, trailer and driver and haul no other pigs. Once delivered to the pre-warmed wean to finish site of 82-83 degrees F, pigs are initially sorted by size and body condition. Pigs will be fed, and treated differently based on size and also provided a little different environment at the start and as time goes on. Bigger pigs are placed on the fan and tunnel ends of the rooms with smaller pigs kept towards the center. All pigs are provided with zone heat of 90+ degrees and comfort boards on arrival but these are kept in place longer on the smaller end pigs up to 2-3 weeks if needed. Water is made immediately available to all pigs through either a dripper system or flushing of water cups until the pigs become acclimated to using the drinkers on their own which is usually a couple of days. The smallest 10% of pigs are also provided with creep bowls for specialty starter products and gruel feeders for gruel feeding 2 to 3 times a day in small amounts or as often as possible. Pen walks make up a big part of pig care looking daily at every pig, looking for those not starting well or in need of treatment, creep feeding on the comfort boards, top dressing with restart and or potato starch, flushing of water cups, checking feed availability and adjusting feeders, putting down drying powder if needed, checking zone heat and temperatures, checking humidity levels, feeling for drafts, pulling of sick pigs or those not starting well to a designated sick pen area where a modified environment is provided and more intensive care delivered, adjusting of inlets, etc. With all of this the most important part is paying attention to detail, addressing everything every day and not walking past or putting off pigs that need attention today or other issues within the barn and the environment of that pig that need to be addressed today.

Nutrition and Vaccines

SFI does have its own on staff nutritionist who formulates cost effective rations that best meets the needs of the pigs. We also deliver a fairly robust vaccination program to protect the pig best we can including circovirus, mycoplasma, erysipelas, flu, E.coli, salmonella, ileitis, PRRS, and some bacterial autogenous vaccines. Of course in addition, under veterinary direction the use of antibiotics both in the water and injectable, and in nursery diets, play an important role in treatment of animals.

CONCLUSION

We at Schwartz farms are not promoting a certain way of doing things, we are just simply giving you a look at the way we conduct our business which has worked well for us over the years. Our model certainly does not and will not work for everyone but perhaps may spark some thoughts about your own operation. With that said, I can say with some certainty that taking care of livestock is a hands on, detail oriented business and the success or failure of that business can be very strongly tied to the strength and commitment of the people it employs and the people it partners with.

ACKNOWLEDGEMENTS

John Schwartz-CEO of Schwartz Farms Inc.

Sheila Schmid-Director of Human Resources

Mark Schwartz-Production Lead

HOW DO I GET IT RIGHT?

POST WEANING DISEASE CONTROL – A UK PERSPECTIVE

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ABSTRACT

Climatically, Canada is such a different country to the UK when it comes to pig production, and N. America has a number of endemic disease problems that fortunately we have not got yet. Overall though, swine infections are similar in many ways and occur in patterns of infection during the production period. Younger animals, especially weaners and growers, are more susceptible to a number of husbandry and environmental factors as well as stresses, which can trigger disease outbreaks. *Escherichia coli* is probably the most common problem associated with post-weaning diarrhoea but there are several other infections that can be brought on depending on what infections are present on the farm, the immunity in the herd whether natural or vaccine stimulated and also what medication programmes are used or not.

The different common patterns of disease in pigs are examined and the best ways of control will be discussed in the workshop.

INTRODUCTION

Canada is such a different country climatically to the UK (even to Scotland) and the long, cold winters must bring on some difficult challenges to pig production – keeping animals warm in the winter, temperature fluctuations and ventilation issues. The former is a challenge to newly weaned pigs in particular and the latter, or lack of it brings on problems with respiratory and systemic infections. The infection mix can also make a huge difference to productivity and the pig's performance, and how you handle the mixture of infectious challenges at various stages is also vital to optimise production. Your disease organisms are different, e.g. porcine epidemic diarrhoea virus (PEDV), porcine reproductive and respiratory disease syndrome virus (PRRSV) seem to be more pathogenic than the ones we have in Europe, so your understanding of controlling these are probably well embedded already and different from ours.

I will try to review some of the factors that have helped production in the UK and they may or may not be applicable to Canadian production for a variety of reasons, but some might help.

UK PRODUCTION OVERVIEW

The UK has about 400,000 breeding sows and produces approximately 10 million finishing pigs a year. The median herd size is 500-749 sows (29%). The UK sow produces 23.7 pigs/year and 1,917kg of meat/sow (BPEX 2015). We are one of the smaller EU producers and import nearly 50% of pork products as fresh meat or processed meat. One of the major differences is that 40% of our sows are reared and bred outdoors. This is unusual in Europe let alone Canada. We don't castrate boars either, so this reduces handling, stress and open wounds at processing (< 7days of age). Outdoor piglets are not routinely given

iron either, which all minimises handling. Tail docking still is relatively common and piglets weaned/litter are usually 1-2 pigs lower (Table 1) but the concept of ‘**outdoor bred**’ has been successfully marketed to the consumer as ‘**welfare friendly**’.

Table 1. Comparison of indoor and outdoor production performance (BPEX, 2015).

Parameter	Outdoor	Indoor
Pigs born alive/litter	11.36	12.63
Pre-weaning mortality (%)	14.18	11.53
Pigs weaned/litter	9.75	11.16 (+1.41)
Pigs weaned/sow/year	21.82	25.71 (+3.89)
Ave weight of weaned pig (kg)	7.02	7.13
Ave age of weaned pig (days)	26.08	26.56

Once they have been weaned at approximately 4 weeks of age they come indoors. For me, weaning at 4 weeks rather than 3 weeks has made a substantial difference to post-weaning problems. It is meant to be obligate in the EU but is frequently ignored. There was a combination of events that brought this on in the UK. It was primarily introduced at the time of post-weaning multisystemic wasting syndrome (PMWS) caused by porcine circovirus type 2 (PCV2) to try to reduce the stress of weaning before the vaccines were introduced (Figure 1). However, before this time we had banned gestation stalls in 1999 and the industry was contracting rapidly (-40%). Many farmers had to change their sow management systems and many went outside to reduce capital costs, they also switched to more 3-site production to try to overcome PRRSV, utilising straw yard systems. We also had foot and mouth disease and swine fever outbreaks, which restricted our movement of pigs and damaged our export of breeding stock (PIC, JSR and NPD/ACMC).

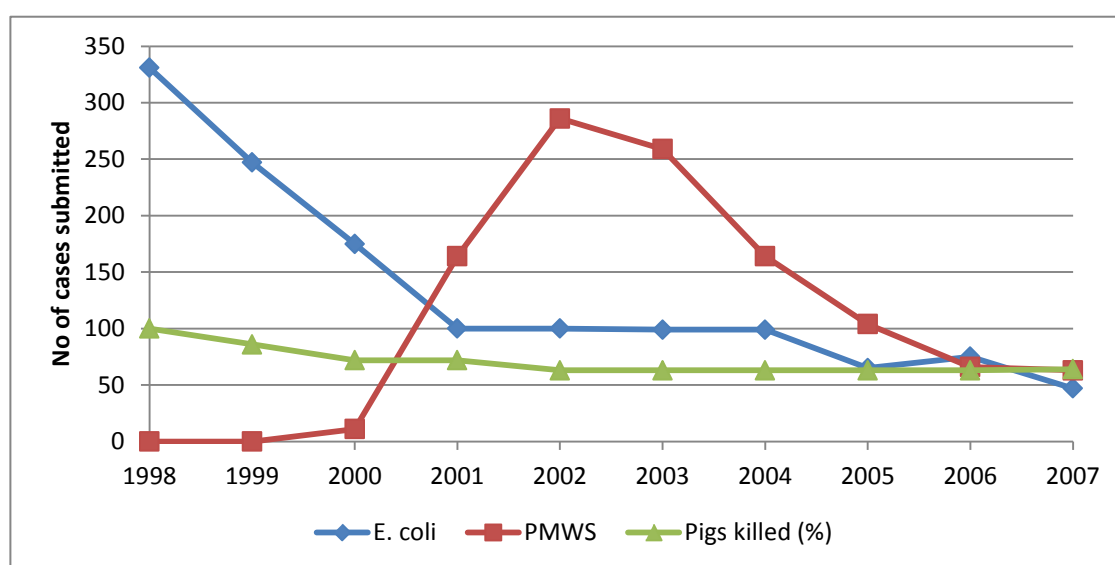


Figure 1. Disease reporting – *E. coli*, PMWS and number of pigs killed (VLA/BPEX).

So many changes occurred at around the same time which depressed the industry and major cost savings were required. This all led to 4 week weaning, the wider use of straw yards and the widespread use of therapeutic levels of zinc oxide (3500ppm) in the feed in

creep and link diets around weaning to stop post-weaning diarrhoeas, primarily due to *Escherichia coli*. This also reduced the duration of the post-weaning check from 2 weeks to a single week, before the pigs grow on again vigorously. Table 2 provides comparative performance data.

Table 2. Weaner/grower performance in the UK 2014 (BPEX, 2015).

	EU average 2013	UK average	Top third	Top 10%
Ave weight of pigs at start (kg)	7.4	7.5	7.3	7.6
Ave weight of pigs produced (kg)	29.9	37.1	32.4	21.3
ADG (g)	417	502	481	394
Days in herd	-	58	51	34
FCE	1.85	1.71	1.46	1.17
Mortality (%)	2.6	2.8	2.5	2.5

As we were not castrating piglets, the use of long acting cephalosporins such as ceftiofur was not widespread, unlike in the EU and I understand N. America. I suspect that this is the main reason that methicillin-resistant *Staphylococcus aureus* (MRSA) had not been selected for and why it has rarely been reported in England and Wales to date (2 cases). Also, our National Pig Association insisted that any breeding stock being imported into England and Wales were shown to be free of MRSA and US PRRSV. In Northern Ireland this was not the case and now several cases of MRSA in pig herds have been reported, thought to be associated with the importation of Danish breeding stock. Being an island can be helpful regarding international biosecurity.

ENTERIC DISEASES

Common enteric bacterial diseases that are found before weaning and in the weaned/nursery period are summarized in Table 3; infection patterns are illustrated in Figure 2.

Escherichia coli

Infection post weaning is associated with ETEC *E. coli* and affects almost all pigs by giving them a growth check, which we attempt to minimise by reducing stresses and use of zinc oxide as discussed previously. If not controlled properly then this can lead to diarrhoea and even death. It classically comes on 5 days after weaning and used to last for 2 weeks before they grew on again. This is reduced to one week if weaning occurs at 4 weeks of age. After this period, occasional scours were seen after moving at 8 or 12 weeks and bowel oedema can occur a few weeks after weaning mainly associated with VTEC *E. coli*. This can cause sudden death in rapidly growing weaner pigs.

Salmonella spp.

Infections are often not clinical in pigs, but infections normally occur in the growing pig, usually with whatever is present in the weaner/nursery accommodation. The salmonella strains are often different from the sow and piglet with *S. enterica* Typhimurium being the most common in pigs. Clinical disease can develop at almost any time, and may lead to septicaemias, but recently it has been reported more frequently post treatment with

amoxicillin for meningitis in weaners, as it is thought to disturb the gut flora allowing for salmonella overgrowth.

Table 3. Common enteric bacterial diseases in the pre-weaned and weaned pig.

Bacterial species	Disease	Age
<i>Escherichia coli</i>	Neonatal scours	1-3 days
	Piglet scours	7-14 days
	Post-weaning diarrhoea	5-14 days after weaning
<i>Clostridium perfringens</i>	Type C – necrotic enteritis	1-7 days
	Type A – diarrhoea	10-21 days, weaned pigs
<i>Clostridium difficile</i>	Diarrhoea, ill thrift	3-7 days
<i>Salmonella spp.</i>	Typhimurium – occasional diarrhoea, septicaemia, death	Grower pigs 6-16 weeks
	Derby – occasional diarrhoea	Grower pigs 6-16 weeks
	Choleraesuis – septicaemia diarrhoea, death	Finishing pigs 12-16 weeks
<i>Lawsonia intracellularis</i>	Porcine proliferative enteropathy (ileitis)	Grower pigs
	Regional/necrotic ileitis	Grower pigs
	Porcine haemorrhagic enteropathy	Finishing pigs and young adults 16-40 weeks
<i>Brachyspira hyodysenteriae</i>	Swine dysentery	Growers and finishers, 6-26 weeks
		All ages in primary breakdown
<i>Brachyspira pilosicoli</i>	Intestinal spirochaetosis ‘colitis’	Grower pigs

***Brachyspira* spp.**

The incubation period for spirochaetes such as *Brachyspira* spp is 7-21 days so they are more frequently encountered later on in the grower/nursery stage and then they can become affected at any time right through to the fattening period. *Brachyspira hyodysenteriae* is the most severe, but in Canada reports of *B. hampsonii* are also severe involving haemorrhagic diarrhoea and much mucous scour. This can lead to weight loss and even death if not promptly treated. *Brachyspira pilosicoli* is generally milder causing mucoid diarrhoea and slower growth rates and poorer feed conversion efficiency (FCE) but deaths are rare.

***Lawsonia intracellularis* (ileitis)**

Lawsonia, the cause of ileitis, is very commonly found in many farms (>90% in the UK) but does not necessarily cause major disease problems. It is similar in severity to *B. pilosicoli* in many ways, causing a soft diarrhoea and poor performance, but mortality is usually low. In the older pig a sudden peracute infection can cause porcine haemorrhagic enteropathy or ‘bloody gut’, where finishing pigs are found dead with very pale carcasses. It is not usual in grower pigs. Mixed infections can occur so a comprehensive diagnosis using PCR and culture of faecal samples is important.

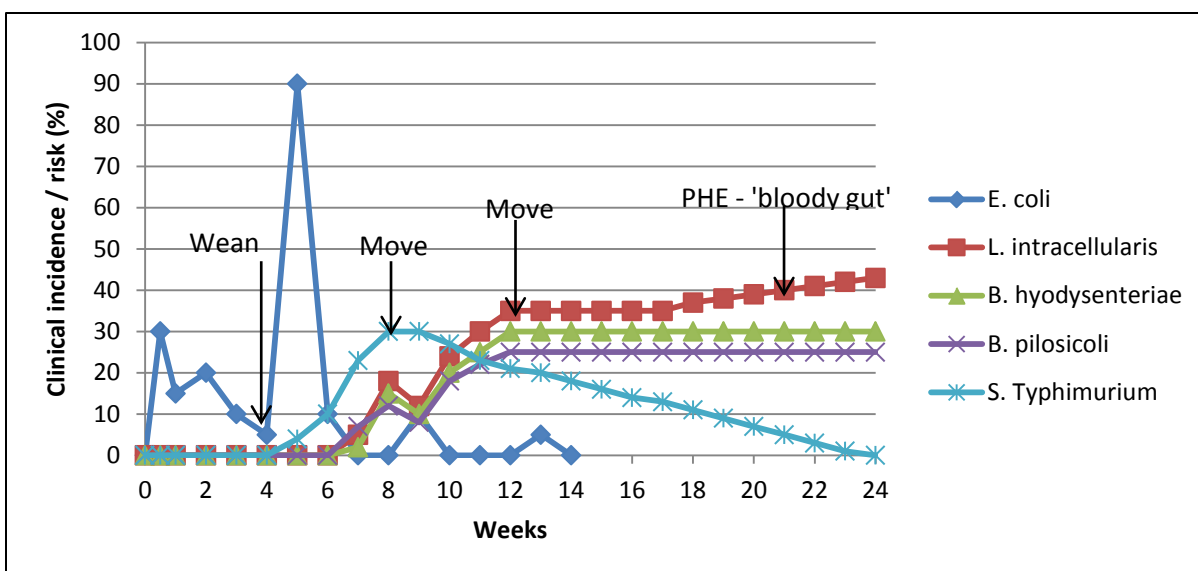


Figure 2. Overview of common enteric agent infection patterns (after Burch et al, 2008).

RESPIRATORY DISEASES

Common bacterial respiratory diseases are summarised in Table 4 and Figure 3.

Table 4. Common respiratory bacterial diseases in the pre-weaned and weaned pig.

Bacterial species	Disease	Age
<i>Pasteurella multocida</i> (D)	Atrophic rhinitis	1-8 weeks
<i>Bordetella bronchiseptica</i>		Nasal distortion lasts for life
<i>Mycoplasma hyopneumoniae</i>	Enzootic pneumonia	Grower and finisher pig
<i>Pasteurella multocida</i>	Mycoplasma-induced respiratory disease (MIRD)	Grower and finisher – secondary invader
<i>Actinobacillus pleuropneumoniae</i>	Pleuropneumonia	Grower and finisher – MDA last for 10 weeks

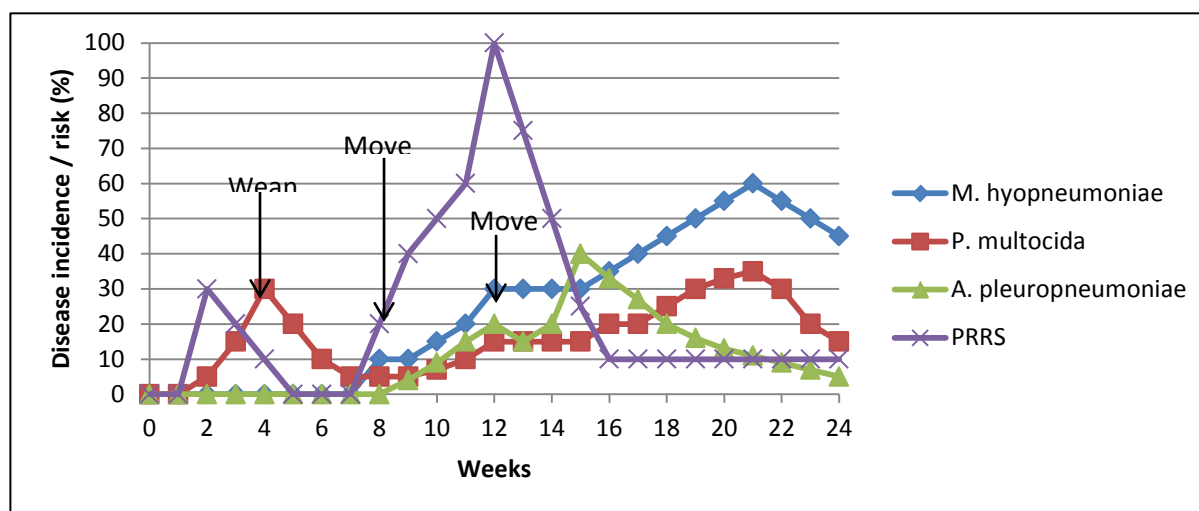


Figure 3. Overview of common respiratory agent infection patterns.

Atrophic rhinitis

Atrophic rhinitis is rarely seen or reported in the UK these days. It was shown to be caused by a dual infection of *Bordetella bronchiseptica* and *Pasteurella multocida*, which produced a dermonecrotxin that damaged the nasal tissue. *Pasteurella* rarely causes respiratory problems in pigs on its own.

Mycoplasma hyopneumoniae (enzootic pneumonia)

Enzootic pneumonia (EP) is caused by *Mycoplasma hyopneumoniae*. *Mycoplasma* can be passed on from sow to piglet but generally it is thought to be more due to older pigs on the same site contaminating naive piglets. Poor ventilation can exacerbate the problem and it takes several weeks for the lesions to develop. One may hear coughing as early as 7-8 weeks of age as stocking density/ventilation is unsuitable but generally it is later on in the nursery and grower phase where it builds up. *Pasteurella multocida* come in at about 50% of EP infections and complicates the problem causing bronchopneumonia. The coughing is acute and they may have increased temperatures and may die if not treated promptly. The presence of PRRS virus also complicates the problem causing the porcine respiratory disease complex (PRDC).

Actinobacillus pleuropneumoniae

Actinobacillus pleuropneumoniae is often thrown in on top of PRDC, although it is a primary pathogen. Mortality can increase from an average of 2-3% to nearly 5% with complicated PRDC. This is the time to start considering depopulation/repopulation with healthy clean stock or partial depopulations and eradication programmes using vaccines and medication.

SYSTEMIC DISEASES

The common septicaemic/bacteraemic causing infections commonly found in weaner pigs are summarised in Table 5 and Figure 4.

Table 5. Common septicaemic bacterial diseases in the pre-weaned and weaned pig.

Bacterial species	Disease	Age
<i>Streptococcus suis</i>	Meningitis, endocarditis, arthritis, peritonitis	2-10 weeks
<i>Haemophilus parasuis</i>	Glässer's disease (arthritis, pericarditis, peritonitis)	2-10 weeks
<i>Actinobacillus suis</i>	Septicaemia	5-28 days
	Pleuro-pneumonia	Weaning to slaughter
<i>Mycoplasma hyorhinis</i>	Synovitis, arthritis	8-10 weeks
<i>Mycoplasma hyosynoviae</i>	Mycoplasmal arthritis	16 weeks plus
<i>Erysipelothrix rhusiopathiae</i>	Erysipelas (dermatitis, arthritis, endocarditis)	Growers, finishers and sows

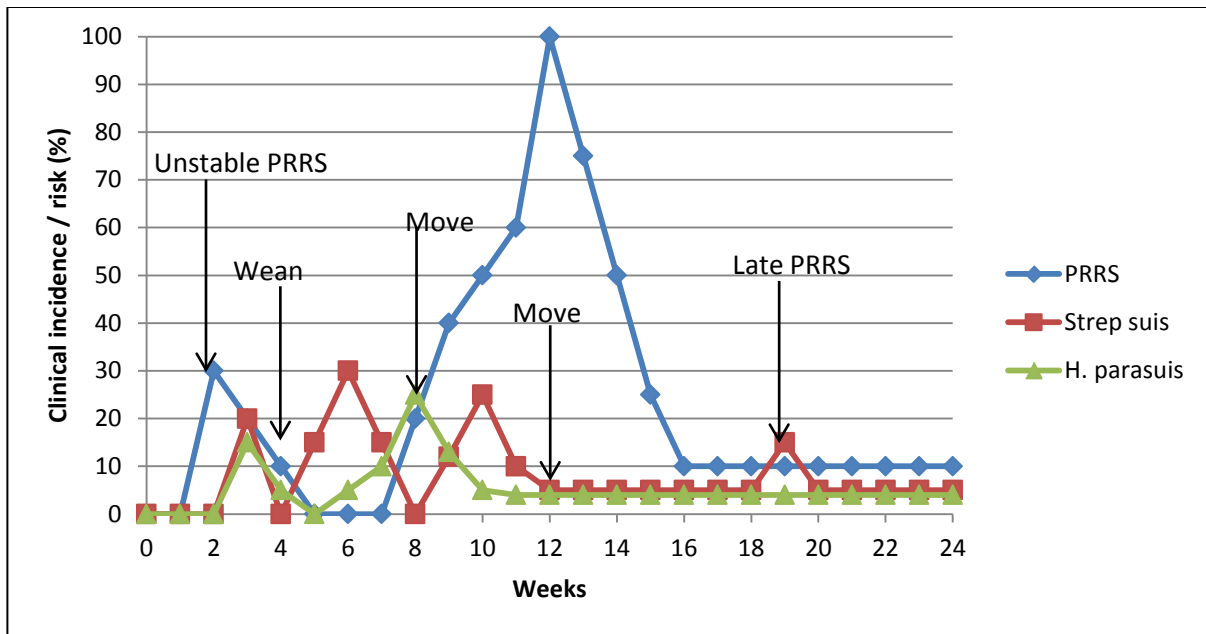


Figure 4. Overview of common septicaemic agent infection patterns.

Streptococcus suis

There are about 35 serotypes but type 1, 2 and 14 are the most common in the UK. They colonise the tonsil, and after a stress, appear to penetrate into the bloodstream and can cause bacteraemia or may multiply and become a septicaemia. The classic septicaemia is the spread around the whole body (where the blood goes) so the organism may settle out almost anywhere. There are predilection sites such as the meninges and brain, hence it readily develops into streptococcal meningitis but can also penetrate joints, the heart and causes endocarditis and pericarditis, the pleura and cause pleurisy and the abdomen causing peritonitis – all the serosal surfaces. Fortunately, they are generally controlled by penicillins and there has been very little resistance development. There are also commercial vaccines for type 2 as well as autogenous vaccines. The stress after weaning can often precipitate a problem and in the UK it is when the weather and temperatures are very variable in spring and autumn. Meningitis is the common problem with pigs lying on their sides, paddling or are found dead. Polyarthritis is also quite common. On some farms it occurs in the growers again after a move or stress. The PRRSV also destabilises the immune response/protection and meningitis can occur especially when there is a PRRSV breakdown, even in finishing pigs.

Haemophilus parasuis (Glässer's disease)

This is very similar in many ways to *S. suis*, another 'suicide'. Again a tonsillar coloniser, it can penetrate the blood stream and can cause septicaemia, and once there can settle out almost anywhere. The common sites though were classically joints – Glässer's disease – but one can get coughing, pneumonia, pleurisy, peritonitis and death. Again there are 15 serotypes and the commercial vaccines are helpful in about 60% of the cases but are not usually giving 100% coverage. Fortunately, they are mainly susceptible to antibiotics. The PRRSV also seems to play a role when the disease is unstable in a herd and can occur before weaning or after.

Actinobacillus suis

Fortunately, it is very rare in the UK (1 reported case) but can cause problems in herds in N. America. It is similar to the other 'suiscides' and generally controlled by antibiotics.

Mycoplasma hyorhinis

Mycoplasma hyorhinis is a common organism on a herd basis but does not always seem to be disease associated. It colonises the respiratory tract like *M. hyopneumoniae* and has been shown to cause low grade pneumonia lesions but does appear to go into the blood stream more easily and settle out in joints and synovial surfaces causing mild to moderate inflammation and swellings on the joints, especially in the hocks etc. Strategic medication can usually control it if it is serious enough a problem.

Mycoplasma hyosynoviae

This can colonise young pigs and they usually develop immunity without developing disease. It is only later on in the finishers that it can cause a polyarthritis and lameness (see Figure 5). There are two forms. If the piglets are weaned away from the sow unit, they may not actually develop immunity and then they receive a challenge when they are 60kg plus and that usually is the most severe form, especially seen in replacement gilts and boars. It has increasingly been reported in the US in finishers. Stress can induce a bacteraemia and often lameness is seen in gilts after transport, 2-3 weeks after arrival.

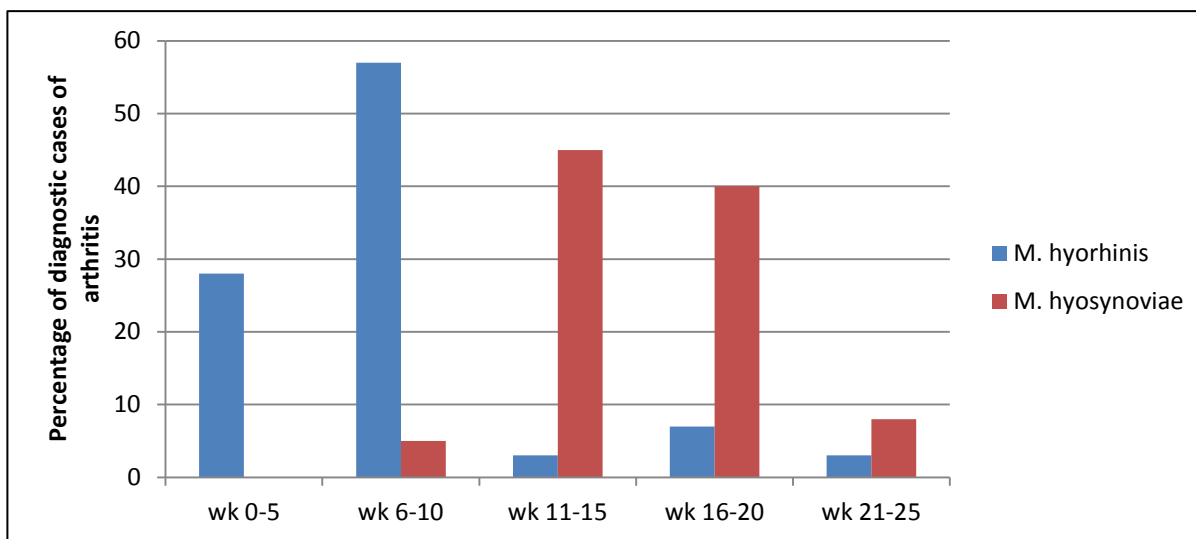


Figure 5. Comparison of the incidence of *M. hyorhinis* and *M. hyosynoviae* diagnostic cases (Gomes Neto et al., 2012).

Erysipelothrix rhusiopathiae

A common cause of lameness and pericarditis in severe, peracute cases but generally the first indications are the diamond shaped skin lesions. Sows are usually vaccinated and this provides protection to the piglets and weaners up to 10 weeks of age. In problem farms vaccinating the young stock is also carried out. Most farms take pot luck in the UK. We saw a lot of peracute cases, when we were trying to clean up herds. The bug is ubiquitous

in the ground and can be carried by birds so picking it up is relatively easy. It does respond to antibiotics but if damage is done internally chronic forms of the disease – heart problems and lameness – can be an issue.

CONCLUSIONS

Although the climate is very different in Canada, many of the diseases are similar. They have similar patterns hence when examining herds it is useful to track through by age group to monitor the presence of enteric problems – diarrhoea and poor condition; respiratory signs – sneezing, coughing, pneumonia, treatment marks and mortality. Lameness, swollen joints and cases of meningitis are also useful to observe. What medications and vaccinations are being used and are they effective is also helpful to get an overall picture of a farm. At the end, necropsies of typical cases give you a good overview of what is going on. Samples can be taken and sent away for testing, for bacterial culture and sensitivity testing, PCR and serology, histology, all add up to the overall picture and diagnosis and what may be the best ways to control them.

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EARLY NURSERY NUTRITION – GETTING PIGS STARTED

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INTRODUCTION

Objectives of nutritional programs may be to consistently produce fast, efficient gains or to optimize the growth response while balancing the cost per kilo gain. Each producer's approach may be slightly different to reach maximum profitability. One commonality across strategies during the early nursery phase is to facilitate the adjustment pigs must go through during the transition from sow milk to solid feed. Optimal intake of the right ingredients stimulates a healthy gut for long term effective nutrient absorption while reducing the incidence of post-weaning diarrhea.

FACTORS AFFECTING POST-WEANING NUTRITION

Changes in Digestive Capability of Young Pigs

Around the time of weaning, the digestive tract undergoes radical changes in physiology, microbiology and immunology (Lalles *et al*, 2007). Most of these changes are motivated by the stress of weaning and occur, in small or large magnitude, regardless of age at weaning. Some of these changes are:

- Increased stomach pH due to decreased acid secretion capacity and decreased lactic acid secretion due to lowered lactose intake. This may increase susceptibility to enteric infections.
- Decreased lactase and other pancreatic enzymes secretion 3 to 5 days post weaning (Figure 1).
- Gastric motility and stomach emptying are reduced. May allow for pathogenic bacteria to proliferate in the intestinal tract.
- Decreased villus height due to atrophy and increased crypt depth in the small intestine occurs within a week after weaning (Wijtten *et al.*, 2011). Villi are responsible for nutrient absorption.
- Intestinal permeability is increased as a result of lower feed intake (Pearce *et al.*, 2015), which is often linked to endotoxin contamination of the blood supply.
- Reduction in the net absorption of fluid and electrolytes and the malabsorption of nutrients in the small intestine immediately after weaning. This could lead to osmotic diarrhea by increasing the quantity of nutrients present in the hindgut.
- In the large intestine, crypt cell numbers are decreased which lowers absorptive capacity and in turn could lead to diarrhea when there is excessive fluid loss from the small intestine (reviewed by Heo *et al.*, 2012).
- Barrier function and active absorption decreases when pigs are weaned at three weeks of age or earlier. This effect is less pronounced when pigs are weaned at four weeks of age or later (Wijtten *et al.*, 2011).

In practical terms, the young pig's digestive system digests milk products more effectively than grain and soybean meal. As the pig gets older, enzymes which allow grain and soybean meal to be utilized more efficiently increase in activity.

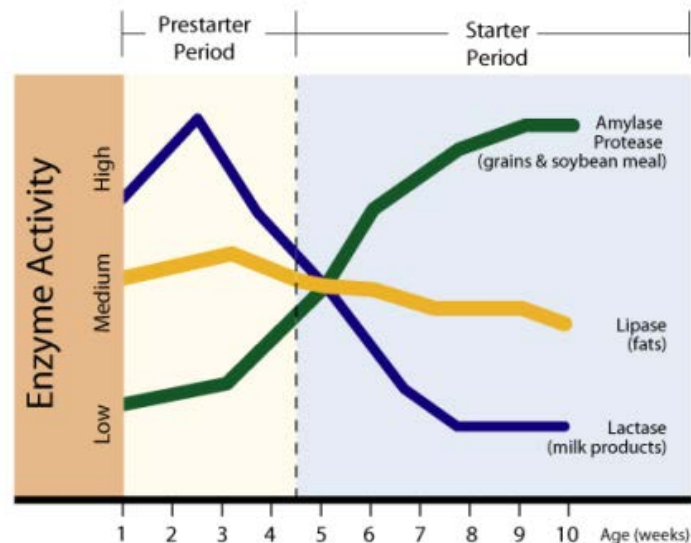


Figure 1. This graph illustrates the relationship between the age of the pig and its ability to digest and utilize various ingredients.

The nutrition program for weaned pigs should be designed to match the pig's digestive development at each stage, by providing highly palatable and digestible ingredients that encourage feed intake and result in maximum performance.

Weaning stress

Besides the physiological responses that occur naturally at weaning, other environmental factors affect the pig's appetite (Lalles *et al.*, 2007) and should not be underestimated. Pigs have to adapt to a new social structure: the separation from the sow and mixing with new littermates, adaptation to different pen designs, accessibility of feeding spaces, learning to recognize the feed, different flooring, new sources and location of water supply, different environmental temperatures and heat sources, moisture in the room, health challenges as a result of commingling animals from different sow farms and stress of transportation, to name the main ones. It takes some time for weanling pigs to find new sources of food, water and comfort. In the best of cases these distractions are what restrict growth performance and it may not be substantial. However, the exposure to a new microflora, establishing hierarchy with pen mates and coping with the separation from the mother can be more challenging to overcome.

Feed consumption

A clear relationship has been established between integrity and functionality of the gastrointestinal wall and feed intake (Pluske *et al.*, 1997). The higher the feed intake during days 0 to 3 post weaning, the longer the villi (Bruininx *et al.*, 2002). Additionally, adequate feed intake after weaning prevents the loss of intestinal barrier function which

protects the pig from toxic molecules that would otherwise pass through the intestinal epithelium (Wijtten *et al.*, 2011). Along with shorter villi, as a result of lower feed intake, nutrient absorption is impaired, resulting in a bad combination of factors leading to reduced body weight gain post weaning and an increased likelihood for opportunistic pathogens to attack the digestive tract and cause diarrhea.

Working to prevent a lapse in feed intake may reduce the time it takes for energy intake to be the same as it was prior to weaning. The nutrition program should be developed towards this goal, and some practical tools to enhance early intake are:

Setting the dinner table. Ensure feed is readily accessible after pigs are situated in their new environment. This means adjusting feeders to be a little more open than normal, allowing pigs to have easy access to feed, thus facilitating better intakes the first 3 to 7 days after weaning. Allow enough feeder space per pig according to the feeder type (i.e., 16 pigs per 38 cm-feeder hole in a dry or wet/dry feeder, or per tube feeder; PIC, 2014). Different feeder designs are available in the industry and many of them are comparable in performance. When assessing which feeders to use, preferably favour open feeders to promote group eating, bright feeder opening to allow light entrance and make feed more visible, and ability to adjust feeders based on pan coverage. Generally, it is a good practice to offer feed and water separate the first few days after weaning while pigs learn to handle the equipment.

They'll have a drink too. Right after weaning, the pressure at the drinker should not be high or it will discourage pigs from approaching it. However, soon after the pigs have found the drinkers and are making use of them, ensure there is enough water flow to provide 0.5 L per minute. Barber *et al.* (1989) measured 11% lower feed intake and hence growth rate in weaned pigs from 3 to 6 weeks of age, when the source of water was restricted to about half the ideal flow rate. Drinker design plays a role too since there may be differences in consumption and waste with different types of equipment (Torrey *et al.*, 2008). Water access is key as well, i.e., height and amount of drinkers available (1 nipple waterer per 10 pigs is best). Ensuring water and water lines are clean could prevent health challenges and opportunistic bacteria from colonizing the gut.

Creep feeding. Offering frequent small amounts of dry but palatable feed to suckling piglets complements the nutrition the piglets obtain from the sows milk, whilst stimulating quick interest in solid feed and developing the eating behaviour of piglets to prepare them for weaning. Several studies have consistently shown that pigs fed creep feed have better initial post weaning feed intake and growth performance than pigs that have not consumed dry feed before weaning (Bruininx *et al.*, 2002a; Sulabo *et al.*, 2009; Yan *et al.*, 2011). Also, if the same palatable and familiar feed is offered post-weaning, it generally results in higher feed intake and fewer diarrhea incidences. Our experience in Provimi is that the benefits of creep feeding are not obtained when regular sow feed is used as the creep feed.

Managing starve-out pigs. Some pigs refuse to eat dry feed. Typically those may be 3 to 5% of the population. Starve-out pigs are identifiable around day 5 or 6 post weaning as slab-sided pigs with gaunt bellies and are not necessarily small framed pigs. To reduce the number of pigs that will be in this category, offer small amounts of feed at least twice a day on a mat or solid floor the first couple of days after weaning. Feed offered on mats or solid floor should be in mash form and highly palatable. Once the starve-out pigs are

identified at day 5, separating them to a different area and offering gruel feed will help get them started on feed.

Lighting. The light schedule in the barn is important in encouraging pigs to find the feeder and increase imitation and curiosity. Bruininx *et al.* (2002) reported a 30% increase in daily feed intake during the first 14 days after weaning when pigs were exposed to 23 hours of light rather than 8 hours. This improvement in feed intake resulted in better growth rate.

Nutrient Density and Composition are Critical

With limited feed intake after weaning and the aforementioned effects on gut health, nutrient density and ingredient digestibility are critical to maximize the nutrients that enter the blood supply for optimal growth. Prestarter diets must be carefully designed with the optimum balance of amino acids, carbohydrates, minerals and vitamins to provide the levels required to maximize gains. Some nutrients are beneficial up to a certain level but in excess may have deleterious effects on performance. Some examples are minerals like calcium and zinc or even amino acids like tryptophan.

Ingredient choices for diets for the weanling pig may include:

Nutrient sources to provide milk protein and immunoglobulins. At the time of weaning, the piglet will stop receiving IgA and other bioactive compounds that were transferred through the sow milk, which makes him susceptible to enteric diseases. In addition, the reduced feed intake at weaning activates intestinal inflammatory responses (Heo *et al.*, 2012). Introducing ingredients in the feed that stimulate feed intake and provide immunoglobulins, such as plasma proteins and some lactose sources, helps the pig cope with the transition from sow milk to dry feed. The benefits of feeding plasma protein during the first week post weaning have been documented numerous times and there is little to no discrepancy on the subject. However, in some production systems the use of plasma has not been welcomed for different reasons, and in those cases it is necessary to find alternatives that provide similar benefits. Based on industry data, some milk ingredients, animal products, peptide products or fermented soybean products can at least partially alleviate the effects of removing plasma. However, with most of them there will likely be high variation on performance due to pig health, environment, and other factors. Although the cost per kilo gain during the first week post weaning often increases with plasma replacement strategies with performance that may not be on par during this period, it is common to see little difference in performance by the end of the nursery period.

Pharmacological levels of zinc and copper. When allowed and pertinent to use, these trace minerals added at higher than nutritional levels (i.e., 2000 to 3000 ppm zinc from zinc oxide or 100 to 250 ppm of copper) reduce the incidence of diarrhea and support optimal growth performance (Verstegen and Williams, 2002).

Organic acids. Acidifiers have multiple modes of action and effectiveness that vary depending on the acid itself. Some of those modes of action include reducing the pH in the stomach and lower gastrointestinal tract, modulating the microbial population by directly killing bad bacteria and aiding in the growth of beneficial bacteria, and lastly, resulting in improved nutrient utilization (Kim *et al.*, 2005).

Probiotics. These are live microbial supplements that alter the microbiota and cause beneficial effects on the pig. These products include yeasts, bacillus and lactobacillus. The response to these products may be variable, but tend to improve performance consistently when pigs are fed diets without antibiotics or plasma proteins, or when pigs are raised in health challenged conditions.

Enzymes. Depending on the substrates the ingredients provide, enzymes may be limited to phosphorus releasing phytases, or to non-starch carbohydrate enzymes specific to the main grain in the diet.

Phase Feeding –Design the Feeding Program for Your System

Required levels of the key ingredients discussed previously decrease as the pig develops and can be replaced by less expensive animal and/or plant nutrient sources. This highlights the need to feed the correct sequence of post-weaning diets that specifically match individual farm weaning weights and ages. A properly phased feeding program utilizing a series of prestarter and starter diets will provide a smooth transition from mother's milk to grain/soy diets in addition to optimizing performance and cost.

For the rapidly changing digestive system of a weanling pig, a 2 or 3-phase nursery feeding program may provide the best nutrition from 6 to 20 kg of body weight. The decision on number of phases should be made based on multiple factors: performance expectations, weaning age and weight, farm historical production data, filling duration of barn, feeding system and ability to feed the proper budget of the first diets to all pigs as they are placed, and the medication/vaccination program. The phases of the feeding program should be revised periodically by considering if pigs are meeting minimum weight targets per feed change, incidence of pigs falling behind, ability to execute the feed budget on farm, transportation efficiency and medication periods, if any, are per label claim.

SUMMARY

At the time of weaning, the natural physiological and immunological changes the pig suffers and the stress generated by all the factors cannot be underestimated. Designing a holistic nutritional program becomes essential. It must incorporate both the scientific aspects of diet design, formulation and their impacts on the gastrointestinal tract, as well as the practical execution of feeding a population of pigs to ensure the right feed is actually consumed and well utilized.

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USING ENZYMES AND INOCULANTS TO MANIPULATE THE FEEDING VALUE OF DDGS FOR YOUNG PIGS

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ABSTRACT

Controlled fermentation of co-products can improve energy availability and gut function through synergistic soluble fiber hydrolysis. This study assessed effects of extended DDGS fermentation on performance and digestive function of newly weaned piglets with light or heavy body weight at weaning fed corn and soybean meal based liquid diets. Liquid diets which contained either DDGS fermented with enzymes and silage inoculants or DDGS added to water immediately prior to liquid feeding were fed to newly weaned piglets for the entire nursery period. Growth parameters were assessed as well as digesta pH and organic acid profiles and the microbiome of the ileal digesta, ileal mucosa, and feces. Feeding of fermented DDGS resulted in improved growth performance late in the nursery period in pigs with light body weight at weaning and altered organic acid profiles in the digesta. The microbiome of all sampling sites was impacted by diet with decreases in alpha-diversity in the ileal mucosa and feces of pigs fed fermented DDGS.

INTRODUCTION

Feeding diets with a high insoluble:soluble fiber ratio has been suggested as a strategy to improve gut function in newly weaned piglets (Molist et al., 2014) through (1) decreased digesta viscosity (thereby increasing digesta transit and efficiency of digestion, and improving feed intake (FI) (Wenk, 2001; McDonald et al., 2007; Hooda et al., 2011) and (2) reduction of enteric microbial growth (decreasing competition with the piglets for nutrients and possibly pathogen load) (McDonald et al., 1999; Montagne et al., 2004; Richards et al., 2005). Soluble fiber content can be reduced through partial fermentation of co-products with enzymes and microbial inoculants, while also increasing organic acid and probiotic content of liquid fed diets (Brooks, 2003; Zhu et al., 2011). This study was carried out to determine the effects of partial fermentation of corn dried distillers grains with solubles (**DDGS**), which has a naturally high insoluble:soluble fiber ratio, on growth performance and the gut microbiome of nursery pigs fed liquid diets containing DDGS.

METHODS

Liquid diets containing DDGS were fed to newly weaned pigs that had either high or low body weight (BW) at weaning (**HBWi** vs **LBWi**; 4 pens/diet and BWi; 14 pigs/pen). Enzymes (67.2 IU β -glucanase and 51.4 IU Xylanase/g DDGS; AB Vista) and silage inoculant (360,000 CFU *Pediococcus pentosaceus* 12455 and *Propionibacterium jensenii* 30081/g DDGS, Lallemand Inc) were added to dry DDGS at the time of liquid feed preparation and delivery (treatment **UNFER**) or allowed to ferment with DDGS (1 to 7 days at 40°C; 16% dry matter; **FER**). Diets were composed of a common base supplement (corn and soybean meal based) for each of three phases (d0-7, 7-20, 20-48), mixed with DDGS (7.5 (Phase 1), 16.25 (Phase 2) and 25 (Phase 3) % of diet dry matter) and water (to

25% dry matter). Per pen apparent dry matter feed intake (ADFI) and individual pig BWs were determined each week for calculating daily BW gain (ADG) and Gain:Feed (GTF). On days 28 and 42 post-weaning digesta was collected from all gastrointestinal sections from 2 pigs/pen and pooled for determination of organic acid concentrations. Ileal digesta, ileal mucosa, and fecal samples were collected from 2 pigs/pen and pooled for bacterial DNA extraction and bacterial profiling.

RESULTS

Despite efforts towards stabilizing fermentations, FER DDGS quality was found to be variable between batches with occasional high acetic acid levels (**FER** n=9; 42.7 ± 8.2 mM lactic acid; 54.6 ± 30.0 mM acetic acid, pH 4.8 ± 0.4 compared to **UNFER** n=3; 17.6 ± 1.4 mM lactic acid; 3.9 ± 0.7 mM acetic acid, pH 5.6 ± 0.3). Overall there were no differences ($P > 0.10$) in ADG and ADFI (Table 1). Growth performance of pigs on FER DDGS was depressed in Phase 1 and 2 in both LBWi and HBWi pigs. For d42-48, LBWi pigs fed FER DDGS had greater ADG ($P < 0.05$), resulting in higher end BW ($P = 0.050$).

Organic acid molar ratios and total concentrations are shown in Figure 1 and 2 for HBWi and LBWi pigs respectively. In digesta, total organic acid concentration and pH did not differ between treatments ($P > 0.10$), with the exception of higher total organic acid concentration in the cecum of HBWi pigs fed Unfer DDGS on D28 ($P < 0.05$). and higher ileal pH in LBWi pigs on FER DDGS on D42 (6.28 vs. 6.97 ± 0.18 , $P < 0.05$). Digesta fermentation patterns (% of total organic acids), differed as shown in Figure 1 and 2 for HBWi and LBWi pigs respectively. Ileal and cecal patterns of pigs on FER DDGS reflected more complex bacterial fermentation in the distal intestinal tract with higher cecal acetic acid proportionally in both LBWi and HBWi pigs fed FER DDGS on D28 ($P < 0.05$). On D42 the ileum of LBWi pigs fed FER DDGS tended to have higher acetic acid proportion ($P < 0.10$) while the ileum of HBWi pigs fed FER DDGS had greater n-butyric proportions ($P < 0.05$), with a tendency toward lower lactic acid proportions ($P < 0.10$).

Alpha diversity of the ileal mucosa and fecal microbiome was lower in pigs on FER DDGS ($P < 0.05$), but not affected in the ileal digesta ($P > 0.10$). Pigs on UNFER DDGS had enriched Firmicutes populations in the ileal digesta and mucosa, with butyrate producing genera enriched in the mucosa. Conversely, pigs on FER DDGS had enriched fecal populations of the probiotic containing class Clostridia. Pathogenic bacteria appeared to be enriched in the feces of pigs on FER DDGS (*Slackia* and *Vibrio*) and ileal digesta of pigs on UNFER DDGS (*Acinetobacter* and *Pseudomonas*).

DISCUSSION

Particularly low lactic acid and high acetic acid levels in the third and subsequent batches of fermented DDGS is most likely the cause of poor comparative performance during Phase 2 for HBWi pigs fed FER DDGS. The lesser impact on LBWi pigs fed FER DDGS is of interest, and is perhaps due to lower overall intake of both diets by LBWi pigs during this time and poorer ADG compared to HBWi pigs. In spite of unforeseen variability in quality of fermented DDGS batches, feeding FER DDGS resulted in improved growth performance of LBWi pigs late in the nursery period when DMI begins to increase dramatically, suggesting improved nutrient availability and gut function. This observation may be due to a lesser ability of LBWi pigs to utilize soluble fiber components of DDGS

Table 1. Growth performance for nursery pigs with heavy or light body weight at weaning (BW_i) fed liquid diets containing DDGS fermented (FER DDGS) or unfermented (UNFER DDGS).

	Heavy BW _i		SEM	P-Value	Light BW _i		SEM	P-Value
	UNFER DDGS	FER DDGS			UNFER DDGS	FER DDGS		
Number of Observations (pens) per treatment	4	4			4	3 ¹		
Body Weight (kg)								
Day 0	7.6	7.5	0.03	0.581	5.8	5.8	0.02	0.129
Day 7	7.9	7.8	1.0	0.743	6.3	6.4	0.1	0.406
Day 21	12.4	11.6	0.2	0.004	9.6	9.3	0.1	0.223
Day 42	25.5	25.3	0.6	0.797	19.6	20.0	0.5	0.621
Day 48	-	-	-	-	24.5	25.8	0.5	0.050
Apparent Daily Feed Intake (g DM/pig)								
Phase 1 (Day 0 to 7) ²	195	203	11	0.617	190	168	3	0.001
Phase 2 (Day 7 to 21)	370	371	8	0.949	318	273	13	0.038
Phase 3 (Day 21 to 42)	945	985	33	0.407	700	746	23	0.168
Overall (Day 0 to 42) ³	581	605	16	0.360	509	540	19	0.328
Week 7 (Day 42 to 48)	-	-	-	-	1136	1314	72	0.071
Average Daily Gain (g/pig)								
Phase 1 (Day 0 to 7)	38	42	15	0.856	85	72	15	0.584
Phase 2 (Day 7 to 21)	323	264	15	0.016	239	208	15	0.252
Phase 3 (Day 21 to 42)	622	648	15	0.231	476	502	18	0.327
Overall (Day 0 to 42)	424	424	14	0.989	386	404	15	0.439
Week 7 (Day 42 to 48)	-	-	-	-	773	941	60	0.042
Gain:Feed (g:g)								
Phase 1 (Day 0 to 7)	0.20	0.20	0.07	0.960	0.46	0.44	0.06	0.873
Phase 2 (Day 7 to 21)	0.86	0.72	0.02	0.001	0.75	0.77	0.04	0.780
Phase 3 (Day 21 to 42)	0.66	0.67	0.03	0.833	0.66	0.69	0.04	0.720
Overall (Day 0 to 42)	0.73	0.70	0.02	0.426	0.76	0.75	0.03	0.838
Week 7 (Day 42 to 48)	-	-	-	-	0.69	0.72	0.05	0.698

¹One observation is missing from the LBW_i pigs fed fermented DDGS in Phase 3 due to malfunctioning of the liquid feed system impacting feed delivery.

²Uneaten feed was removed from troughs 1 hour after feeding during Phase 1 to encourage feed intake while establishing feed intake patterns. Values for Phase 1 are therefore overestimated.

³Overall growth data for LBW_i pigs is calculated as week 0 to 6.

and thus benefiting more from partial fermentation. In addition, pigs potentially compromised by light BW at weaning may benefit more from dietary strategies which affect gut development. Dietary effects on digesta organic acid characteristics suggest altered bacterial metabolism particularly in the ileum and large intestine with partial DDGS fermentation. The increased acetic and butyric acid proportions in the ileum of pigs on FER DDGS suggest less soluble fiber present for bacterial fermentation in these pigs due to prior hydrolysis. While partial fermentation of the DDGS seems to have altered bacterial metabolism and gut function in a way that improved growth performance, alterations to the microbiome may result in pigs fed FER DDGS being more susceptible to enteric disease. The reduced diversity in the ileal mucosa and fecal microbiome and increased populations of potentially pathogenic bacterial populations therefore indicates a possible benefit to maintaining some soluble fiber in nursery pig diets.

CONCLUSIONS

Controlled partial fermentation of high-fiber co-products has the potential to improve nursery pig growth performance. This may be attributed to initiation of fiber digestion prior to feeding, as evidenced by alteration in microbial metabolism in the gastrointestinal tract. Success in this feeding strategy requires careful control of fermentation conditions to reduce the establishment of microbes yielding unfavourable fermentation products such as acetic acid. Partial fermentation appears most useful in pigs with low body weight at weaning, suggesting a particular benefit to animals exposed to a stressor. Effects on the microbiome are of interest and suggest that co-products with a low initial insoluble:soluble fiber ratio may be a better substrate for partial fermentation, so as to provide a small degree of soluble fiber at feeding. This may contribute to the maintenance of a healthy gut microbiome more resistant to disease, while potentially reducing negative effects of soluble fiber in the diet.

ACKNOWLEDGEMENTS

Funding was provided by OMAFRA, NSERC, and industrial partners of the Swine Liquid Feeders Association (www.slfa.ca).

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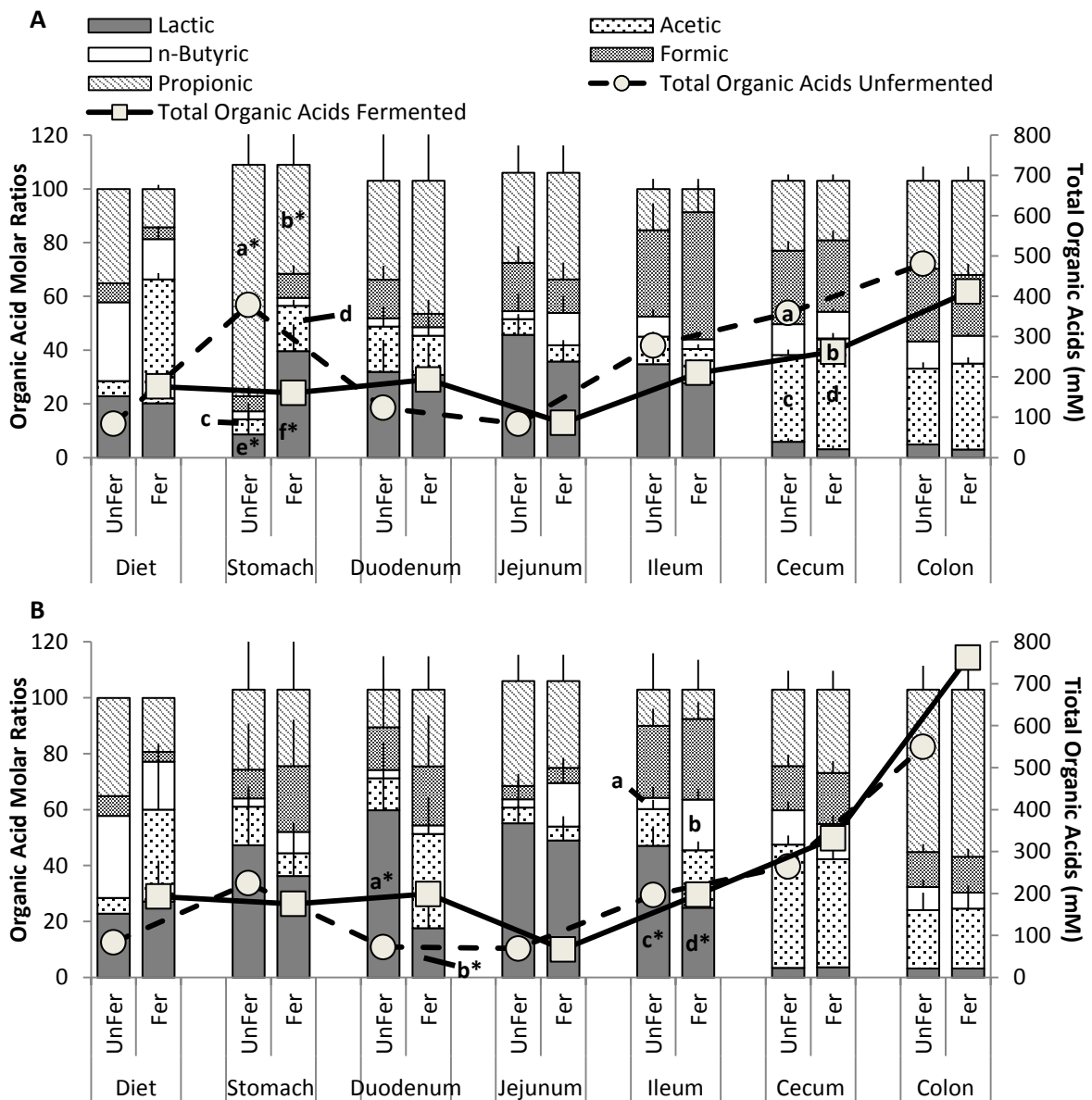


Figure 1. Digesta organic acid molar ratios and total organic acids of heavy weaning body weight (7.6 ± 0.6 kg) nursery pigs liquid fed UNFER and FER DDGS on A: day 28 post-weaning and B: day 42 post-weaning. Different letters within a gastrointestinal region represent significant differences ($P < 0.05$). Starred letters represent trends ($P < 0.10$).

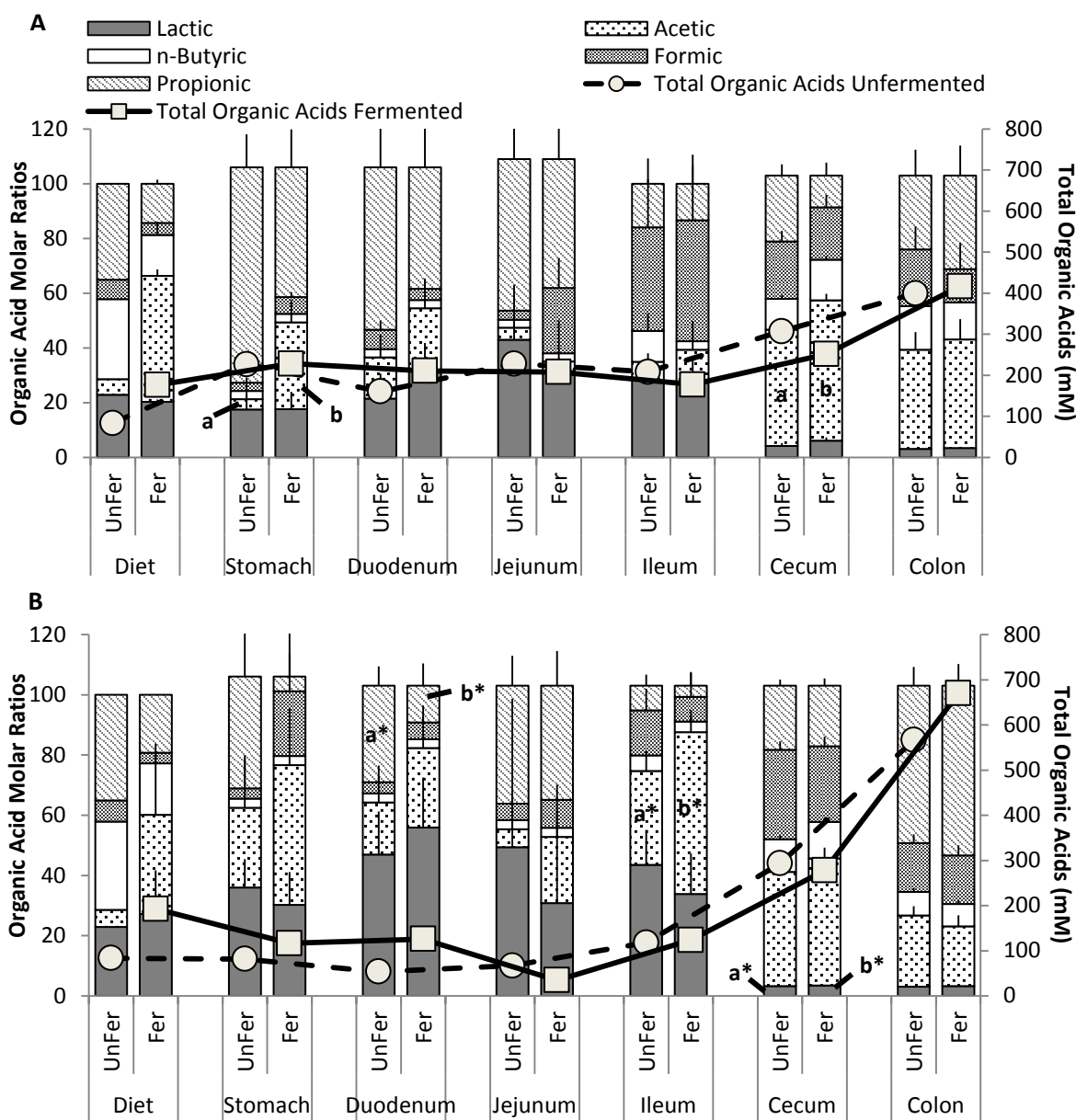


Figure 2. Digesta organic acid molar ratios and total organic acids of light weaning body Weight (5.8 ± 0.6 kg) nursery pigs liquid fed UNFER and FER DDGS on A: day 28 post-weaning and B: day 42 post-weaning. Different letters within a gastrointestinal region represent significant differences ($P < 0.05$). Starred letters represent trends ($P < 0.10$).

FEEDING FOR CARCASS VALUE: GRADING SYSTEM IMPLICATIONS

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ABSTRACT

Over the last several decades, carcass value and returns to producers have mainly been determined by weight and estimated lean yield. A national carcass grading system was in place, but this was removed in favour of individual systems implemented at the packer level. Valued attributes such as meat colour, marbling, fat hardness and fatty acid composition were not part of the grading system. However, considerable efforts have gone into gaining value by producing pork to satisfy market desires for specific colours, marbling levels, firmer fat and healthy fatty acid profiles, while maintaining an overall pleasurable eating experience. With renewed interest in developing a national grading system, it is important to understand what attributes could be included in the grading system and how these can influence carcass value. To assist in these efforts, it's important to understand how feeding can influence carcass merit and meat quality attributes, and how new and older technologies could be useful for capturing value in an updated national grading system.

INTRODUCTION

The term carcass value may not have the same meaning for producers, processors, packers, retailers and consumers, but it is often used interchangeably. Depending on the value chain sector considered, carcass value might be carcass yield, carcass merit or meat quality attributes. Over the last several decades, carcass value and returns to producers have mainly been determined by carcass weight and evaluation of muscle depth and fat thickness (estimated lean yield). The first national carcass grading system was implemented in 1922. Since the first policies were set out, the grading system continuously evolved in order to suit industry desires and facilitate trade. The pork grading system was, however, discontinued by Agriculture and Agri-Food Canada in 1996 in favour of individual systems implemented at the packer level. For instance, many plants have adopted their own meat quality selection systems for the Japanese market and premium branded programs for Canada. Valued attributes such as meat colour, marbling, fat hardness and fatty acid composition have not been part of the grading system, but considerable efforts have gone into gaining value (e.g. Premium Branded Programs in the Canadian Marketplace) by producing pork to satisfy market desires for specific colours, marbling levels, firmer fat and healthy fatty acid profiles, while maintaining an overall pleasurable eating experience. With renewed interest in developing a national grading system, it is important to understand how feeding can influence carcass merit and meat quality attributes, and how new and older technologies could be useful for capturing value in an updated national grading system.

All carcass grading systems attempt to describe carcasses in terms of two main pillars including quantity, either total lean or saleable yield that a carcass contains, and quality, either of the carcass or muscle itself. Grading systems have been developed by countries

to mainly facilitate trade by providing a common and unambiguous language for describing commercially important attributes of carcasses (Allen and Oka 2004). Grading systems also provided a means of settlement for producers according to the quantity or quality of what they produce. For instance, in Canada, the pork grading system was developed “to ensure that producers receive a fair, impartial and equitable return based on the lean yield of their carcasses”. Feedback obtained from the grading system can then also act as a driver for genetic selection. Getting pork quality right, however, also required nutrition selection. In people, the old saying is “you are what you eat”, and this is also true in pigs. Every tissue in a hog carcass was created from the feed, water and air consumed. In addition to nourishing hogs, feed affects the quality of the carcass, appearance, weight, pork composition, the aging process and overall health and well-being.

ASSESSING CARCASS VALUE

Quantity: Lean meat and saleable yield

In most pig producing countries, pork carcass value is estimated based on carcass weight and lean yield. At this point, it is worthwhile to define two different approaches that have been used to define yield. Carcass lean yield is defined as total weight of muscle tissue in the carcass side expressed as a proportion of side weight – usually through dissection; intramuscular fat (marbling fat) is included. Commercial or saleable yield is, however, based on retail cuts defined by specifications and expressed as a proportion of side weight; usually contains lean (including marbling fat), seam or intermuscular fat and a specified depth of subcutaneous fat; may or may not include bone. Usually, grading systems are based on predicted yields, either carcass lean yield or commercial / saleable yield obtained by equation or anatomical measurements. Currently, Canadian lean yield is expressed in terms of percentage of side weight and it is defined by the algorithm:

$$\text{Percentage lean yield} = \frac{\text{weight (Boneless DeFatted ham + boneless loin + tenderloin + BDF butt + BDF picnic + skinned belly + side ribs)}}{\text{side carcass weight}} \times 100$$

The present equation is based on the 1992 National cut-out with equations readjusted in 1994 (Canadian Pork Council 1994). Since then, genetics have evolved and nowadays, pigs are much heavier in relation to those sampled in the 1992 National cut-out.

New technologies have been implemented with different success to assist in carcass yield estimation or prediction. For instance optical probes such as: Destron (Anitech Identification System Inc., ON), Fat-O-Meat'er (FOM) (Carometec A/S, Herdev, Denmark. Former SFK Ltd), Hennessy Grading Probe (HGP) (Hennessy Grading Systems Ltd., Auckland, New Zealand), Capteur Gras-Maigre (CGM) (Sydel, Lorient, France), Danish Classification Center (Carometec A/S, Herdev, Denmark); ultrasound probes: Ultrafom (UFOM) (Carometec A/S, Herdev, Denmark), Carcass Value Technology (CVT) (Animal Ultrasound Services (AUS), Inc, Ithaca, NY, USA), AUTOFOM (Carometec A/S, Herdev, Denmark) or Camera vision systems: VCS (e+v[®] Technology GmbH, Oranienburg, Germany) and CSB-Image-Meater[®], Germany). All these technologies rely on the yield algorithms applied in their software, either for total lean yield or saleable yield.

An extensive review on the nutritional factors associated with lean:fat ratios (carcass leanness and marbling) has been published by Pettigrew and Esnaola (2001). Essentially,

carcass total lean yield can be increased by increasing the amount of protein accreted (deposited), by reducing the amount of fat accreted, or both, if the flow of nutrients that go to fat deposition can be redirected toward protein deposition, which will increase leanness. The amount of protein that a pig can accrete each day can be limited by either nutritional factors or non-nutritional factors. Non-nutritional factors put a ceiling on the amount of protein the pig is capable of accreting. The most important of these factors is genetics, but sex, health, and various environmental factors appear to have significant effects. The supply of nutrients also determines how much protein the pig can accrete. Therefore, protein accretion can be limited by the potential of a given pig in its environment (non-nutritional factors), by energy intake, or by amino acid intake. Protein deposition requires both energy and amino acids. If energy intake is limiting, increasing the amino acid levels of the diet does not increase protein deposition or leanness. If amino acid intake is limiting, increasing the energy intake will only make a pig fatter. In addition, there are other nutritional factors such as chromium, conjugated linoleic acid, betaine, trimethylamine oxide, carnitine and creatine where supplementation into the pig diets can play a role in the lean and fat content of the pig carcass (Pettigrew and Esnaola 2001). In this sense, some of the practices in the past have been to supplement finisher diets with betaine or carnitine to produce leaner carcasses, although scientific support for these additions is not strong (Matthews et al. 1998; Overland et al. 1999; Waylan et al. 2002). Chromium is available for the same purpose; a number of research studies were performed to determine its effects with contradictory results (Pettigrew and Esnaola 2001).

More recently, looking for ways to improve lean yield has deviated from attempts to find 'magic' supplements or dietary manipulations to improving barn averages. More focus is on developing systems to capture value by minimizing within barn variation, and using feeding resources as efficiently as possible. This includes tailoring systems to predict and meet individual animal requirements (Pomar et al. 1999; 2011). This not only includes measuring individual animal weights, feed intakes, and providing diets to meet requirements, but also trying to use remote sensing (video and infra-red thermography) to factor in behavior and animal metabolism into prediction algorithms (Weschenfelder et al. 2013).

Quality: Carcass merit and meat quality attributes.

In contrast to carcass lean where different measures have been applied to improve yield performance, there has been less focus on strategies to improve aspects of pork quality. The hypothetical scenario for an eventual implementation of a pork grading system might be to award premiums or rewards for improved aspects of pork quality or penalties for poor quality. Financial rewards could be similar to the system put in place in the early 90s when rewards were provided for producing leaner pigs. For this reason, it is important to fully understand which attributes could be of interest in the grading system and how these can influence carcass value, and importantly, how some nutritional interventions could affect them.

Colour, pH and water holding capacity

In 2007, the Pork Quality Perceptions audit (Young 2011) was performed on target clientele (retail buyers, HRI buyers, importers, distributors and purveyors), target markets (Canada, US, Japan South Korea, China/HK, Mexico and Australia) and research sample (230 face to face and telephone interviews conducted in six languages). This audit

reported that meat colour (75%), firm meat texture (75%), flavour (71%) and juiciness (71%) were the main pork quality attributes in terms of positively affecting the purchase decision of pork (Table 1).

Table 1. Pork quality attributes rated on a scale of 1-10 in terms of positively affecting the purchase decision.

Quality Attributes	8-10 Rating: High impact on purchase decision
Meat colour	75 %
Firm Meat Texture	75 %
Flavour	71 %
Juiciness	71 %
Water holding capacity	63 %
Fat colour	58 %
Tenderness	56 %
Marbling	50 %

These results suggest that meat purchasing decisions continue to be influenced by colour when selecting fresh meat in the retail case. Colour is a very important visual indicator of quality for many end-user customers across all channels and all export markets. For instance, consumers use discolouration as an indicator of freshness and wholesomeness. The colour of pork is influenced by the pigment content, the chemical form of the pigment and by the meat structure. The muscle pigment content varies between pig breeds (Lindahl et al. 2001) and is also related to the metabolic type of the muscle (Beecher et al. 1965; Beecher et al. 1969). Along with these pre-harvest factors, meat colour is also closely associated with dietary supplementation (Pettigrew and Esnaola 2001).

Early reports of the prevalence of PSE (pale, soft and exudative) and DFD (dark, firm and dry) pork implied quite low levels of the problem (Warris 1987). However, a more recent audit of pork quality perceptions (Young 2011) have suggested much greater incidences (Table 2). Pork users interviewed reported negative pork quality deviations including PSE (22%) and DFD (20%). Time off feed prior to slaughter can reduce muscle glycogen content at slaughter, and result in increased ultimate meat pH. The data in Table 3 demonstrate that too short a period of feed deprivation can result in an increased incidence of PSE pork, whereas too long a feed deprivation can increase the incidence of DFD pork (Schaefer et al. 1995). These data suggest that depriving feed for 2 h or less yields pork with a light colour, low pH and high drip loss. The longest periods of pre-slaughter feed deprivation, however, produced dark-colored pork with high water holding capacity. From a nutritional perspective, however, it is known that supplementing dietary magnesium can reduce the incidence of PSE and increase water-binding capacity, colour and pH (D'Souza et al. 1998; D'Souza et al. 1999). Consequently, supplementing magnesium in pre-slaughter diets has been recommended as a means to improve pork quality, particularly in stressed pigs. In addition to magnesium, pre-slaughter sodium oxalate supplementation has been reported to be beneficial, resulting in higher early post-mortem pH and lower water loss from the muscle (Kremer et al. 1999). The trick is, however, to know when addition of stress reducing supplements will be cost effective. In future, it may be possible to include environmental factors (temperature, humidity, crowding, etc...) combined with remote sensing of pig metabolism and behavior to help define when nutritional intervention may be necessary, or when a resting / refeeding period may be cost effective.

Table 2. Quality complaints reported in the Pork Quality Perceptions Audit 2007 (Young 2011).

Complaints (%)	PSE	DFD
Yes	22	20
No	75	79
Do not know	3	2

Table 3: Effect of pre-slaughter feed deprivation during transport and handling on pork quality (Schaefer et al. 1995).

Trait	Time off feed (h)					
	0	2	24	48	72	96
pH (Ultimate)	5.52	-	5.64	5.61	-	-
L*	52.1	47.9	49.0	46.5	44.9	45.1
Water holding capacity, %	-	58.2	60.1	62.5	63.7	66.5
Drip loss	32.0	-	20.0	-	-	-
Colour (1-5, pale - dark)	2.85	-	2.93	2.96	-	-

Marbling and fat quality

Intramuscular fat or “marbling” are the small flecks of internal fat exposed on the cut surface of a muscle. Based on the results of the Pork Quality Perceptions Audit 2007, marbling was reported as a lower impact factor on the pork quality attributes in terms of positively affecting the purchase (Table 1). However, marbling is a major contributor to the natural flavours and juiciness of the cooked product. For these reasons, pork marbling is a major quality trait for international markets, especially highly-valued markets such as Japan (Agriculture and Agri-Food Canada 2013). Marbling can be measured visually based on the percentage of internal fat (amount and distribution) using the Canadian Pork Quality Standards scale of 0.0 > 6.0 evaluated across the loin eye after the cut surface has fully bloomed (oxygenated). Intramuscular fat is known to be highly heritable but is also strongly influenced by feeding strategies (Maignel et al. 2013). Carcass fatness and marbling are not perfectly correlated, but in general, nutritional interventions that alter one cause the other to move in the same direction also (Pettigrew and Esnaola 2001). In a new and improved Canadian pork grading system, however, if marbling is to be included as a factor, defining how this will be done will be important. Unlike beef, where marbling is assessed on the cut surface between the ribeye and short-loin, there has been much resistance to cut pork loins. Visually assessing marbling at a different location may be possible. In addition, it may be possible to assess marbling with ultrasound (Newcom et al. 2002), or through other advanced technologies (DEXA or NMR).

Porcine fat quality is also an important factor for determining economic value, nutritional value, and taste. Increased concentrations of unsaturated fatty acids (FA) can lead to soft fat, processing problems, reduced quality and shelf life of processed pork products, and an inability to meet fresh pork export specifications (Carr et al. 2005). Consequently, soft fat is deemed undesirable in multiple countries, such as Canada (Soladoye et al. 2015), the United States (USDA, 1985), and the European Union (Russo, 1988). In fact, soft fat is the main cause for downgrading and lowered price in Japan due to its reduced sliceability and lower processing quality (Irie and Ohmoto, 1982). Beyond issues with fat softness, increased contents of unsaturated FA can also reduce oxidative stability and negatively

affect the flavour of meat (Shahidi, 1994). On the other hand, since 1950, scientific evidence has highlighted the link between lipid intake and potential health effects in humans (Hooper et al. 2012). Even if the issue remains controversial (McAfee et al. 2010), most dietary recommendations advise a lower saturated fatty acid (SFA) and higher omega-3 polyunsaturated fatty acid (PUFA) intake, in order to reduce the risk of cardiovascular disease (World Health Organization, 2003). Several strategies, mainly modulating genetics and diet, are currently investigated to enhance the fatty acid (FA) composition in animal products destined for human consumption (Scollan et al. 2014). Pigs are monogastrics and categorized as homolipoid organisms (Shorland 1950), meaning their FA composition closely reflects the FA composition of their diet. Hence, several studies increasing dietary unsaturated FA in pigs have been performed (Dugan et al. 2015). However, the increased concentration of dietary unsaturated FA in pigs can have negative effects on fat quality. To combat fat softness, supplementing pig diets with conjugated linoleic acid (CLA) has been found to increase belly firmness (Eggert et al. 1999) and also increase lean (Dugan et al. 1997, Heckart et al. 1999), but feeding CLA is still not approved in Canada. Improving oxidative stability of pork fat can also be increased by vitamin E supplementation and this can improve shelf-life (Buckley et al. 1995; Morrissey et al. 1998; Pettigrew and Esnaola 2001). Reasons for supplementing vitamin E are, however, less compelling for pork versus beef, as vitamin E can have much more dramatic effects on beef colour and shelf-life of ground beef.

Iodine value (IV) estimates the proportion of unsaturated FA, and theoretically indicates carcass fat firmness (Eggert et al. 2001). The IV of fat is calculated from the FA composition using an equation (AOCS, 1998). Chemically measuring IV is time consuming, adds expense and would not be practical for factoring into a grading system. Recently, however, near infrared (NIR) technology has been used to successfully predict pork fat IV values using benchtop (Gjerlaug-Enger et al. 2011; Prieto et al. 2014b) and portable equipment (Prieto et al. under review). If portable NIR could be used to measure IV immediately after slaughter without sample treatment, it could lead to a number of benefits including development of quality standards and payment grids for different fat qualities. In addition, using portable NIR to measure IV could be used by specialty pork producers for product development and quality control, or by pig breeding companies to assist in selection for desirable fat quality. Even though not implemented in Canada, other countries have previously established IV thresholds for pork fat firmness: 70 for UK (Lea et al. 1970), 74 for North America (Boyd, 1997), or 62 for Switzerland (Müller and Scheeder, 2008); with deductions being charged to suppliers of finished pigs with IV above these thresholds.

Future grading technologies

As with other meat industries, the pork industry is rapidly changing around the world and ongoing research is being carried out into the next generation of grading technologies such as dual energy X-ray absorptiometry (DEXA) (López-Campos et al. 2015; López-Campos 2014), near infrared reflectance spectroscopy (NIRS) (Prieto et al. 2014a) and hyperspectral imaging (Kim et al. 2001). A new Canadian pork grading system might, therefore, be assisted by implementing a mix of older and new technologies to provide a more accurate carcass payment system, and in turn result in optimized carcass cutting and market utilization, improved genetic merit, and utilization as a tool for feedback to producers to improve both pork quality and yield.

IMPLICATIONS

The grading system is back on the pork industry agenda. With renewed interest in developing a national grading system, it is important to understand the attributes that could be included in the grading system and how these can influence carcass value. All carcass grading systems attempt to describe the carcass in terms of two main pillars, the quantity, either total lean or saleable yield, and quality. Carcass leanness is one of the outcomes considered in selection of energy and amino acid densities in diets. The Canadian pork industry is already using some technologies in efforts to improve carcass leanness and yield. In contrast, there has been less focus on methods to improve other aspects of pork quality. However, with a new grading system on the horizon, introduction of new technologies might bring financial rewards for improving pork quality attributes. The pork industry already has the tools to improve quality through nutritional changes that have a direct financial cost. Besides providing appropriate dietary levels of energy and amino acids to improve leanness, targeted supplementation of other nutrients (vitamin E, magnesium, CLA, oxalic acid) can be used to improve pork quality. The adoption of nutrition strategies is, however, waiting for an economic incentive (i.e. a pork grading system that factors in quality attributes). Focusing on individual animal needs, and when nutritional intervention would be cost effective will, however, be a key to improving the bottom line in the pig barn.

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FEEDING FOR CARCASS VALUE – CONSIDERATIONS OF GENETICS

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ABSTRACT

Feeding strategies that increase carcass value are important for producers, packers and the sellers of Canadian pork. However, these strategies also need to consider the costs associated with the feeding strategy. Feed is the most important cost to the producer, representing more than 60% of the costs of producing market hogs. A change to the feeding program can therefore potentially have a large impact on the producer. The benefits throughout the pork production chain must be at least as large as the cost of changing the feeding program and there must be a way for producers to cover the additional cost. Similarly, genetic choices can also increase carcass value, and again, the benefits need to be at least as large as the cost of any changes in genetic choices. However, in contrast to feed, genetic costs to the producer are relatively small and represent only 2.3% of the cost of producing market hogs. The costs of genetic improvement are borne by a relatively small number of genetic suppliers who would need to work on pork quality traits that would add carcass value. The costs to the individual breeding stock supplier could be large, but the benefits would be multiplied across many commercial herds and further along the pork production chain. Small investments in genetics by the whole industry therefore offer large opportunity to increase carcass value. In this case there is a need for the breeding stock suppliers to cover these additional costs, which may be large for them even if the total costs are small for the whole industry. Examples of ways to increase net carcass value include feeding to genetic potential, genetic selection to target specific levels of lean yield or other carcass attributes, and use of genetic selection and feeding strategies to target more specific pork quality attributes such as marbling. Feeding to genetic potential and targeting lean yield have been very effective in the past to increase net carcass value and continue to offer opportunity to do so today. There is increased interest recently in focussing on more specific carcass and pork quality attributes where nutritional and genetic strategies could provide a significant benefit. This increased interest in pork quality and the developments of new technologies to measure and improve pork quality open the door to a tremendous opportunity for increased carcass value. Developments in genomics will allow the industry to enhance specific pork quality attributes where this wasn't practical in the past.

INTRODUCTION

It is well known that both management (including nutrition) and genetics can have a large impact on carcass value. Interactions between nutrition and genetics can also influence carcass value. Although these are powerful tools, a bigger challenge is actually determining what defines carcass value and from that what traits to change. It is particularly challenging considering that value to the producer, value to the packer or value of pork being sold in various markets around the world can be affected by very different factors. Producers, for example will be motivated by genetic and nutritional strategies that enhance growth, feed efficiency, sow productivity and lean yield. Packers will be

motivated by lean yield but may also be interested in other more specific carcass traits such as primal yields, fat hardness or drip loss. Further along the chain there will be interest in pork quality attributes such as colour, marbling and firmness. In the short term, individuals will make decisions to maximize value in their own part of the chain, whether they are producers, packers, further processors or traders. Long term, however, enhancing net value of pork in the market place will result in more value for everyone involved. In addition to the value of products being sold, it is important to keep in mind that to maximize net carcass value, costs at all levels must also be considered.

FACTORS AFFECTING NET CARCASS VALUE

1. Cost to the Producer

For the producer, net carcass value is largely influenced by cost of production. Feeding and genetics can both influence carcass value, but they are also costs to the producer. Feed is by far the largest cost and represents over 60% of total cost per pig marketed. Genetic costs (replacement gilts and semen) on the other hand represent only about 2.3% of the total cost per market hog (Ontario Ministry of Agriculture and Rural Affairs, 2016). Because feed is such a large percentage of the cost, one has to take care that any increase in carcass value is at least as large as any increased feed costs when making nutritional choices. Genetics can also have an impact on carcass value. However, because genetics is a relatively small percentage of the cost, increased carcass value can be realized with relatively little cost to the producer. Consider that all the costs of genetic improvement programs (including delivery to the farm) are covered by 2.3% of the cost per market pig. It would therefore require only a very small increase in cost allocated to genetics to allow genetic suppliers to put much more attention on enhancing carcass value.

2. Income for the Producer

Apart from the market price fluctuations, the grading system is the main factor influencing income to the producer. Grading in most cases is a function of carcass weight, estimated lean yield, grading fat depth, grading lean depth, bonuses and demerits. Carcass weight of course is largely a function of live weight, but it also depends on carcass yield or dressing percent (carcass weight as a percent of live weight). Dressing percent has been shown to vary by sire line (Fortin, 2013) and may also be influenced by nutritional strategies. There are a number of nutritional strategies that can be used to influence lean versus fat deposition, such as energy and lysine levels, phase feeding and split sex feeding. Genetics also has a significant effect on these traits. Most significantly, genetic improvement for lean growth has not only increased lean yield, it has also allowed producers to raise hogs efficiently to heavier weights without loss of lean yield. For many decades there has been effective genetic selection to increase growth rate and reduce backfat (see Figure 1). In the last 10 years, however, instead of selecting to reduce backfat, selection has shifted to increase carcass lean (see Figure 2). Heavier carcass weights with an optimal level of lean yield have meant more income per hog to the producer and at the same time more value for the packer.

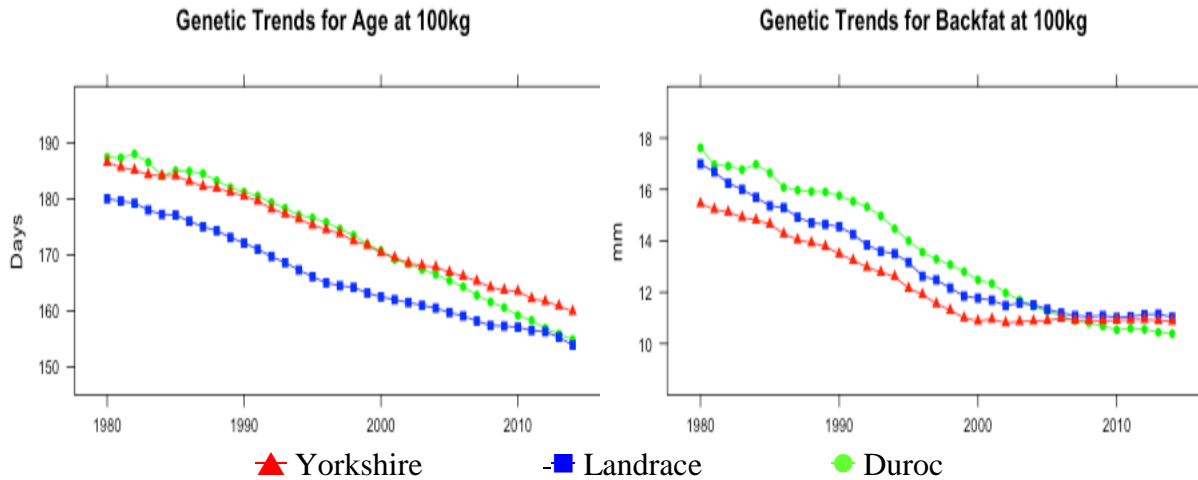


Figure 1. Genetic trends for backfat and growth rate in the Canadian Swine Improvement Program, (Canadian Centre for Swine Improvement, 2015).

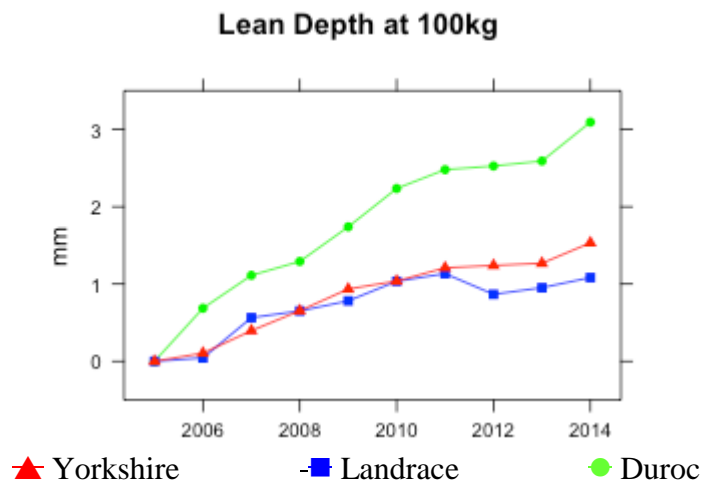


Figure 2. Genetic trends for loin muscle depth in the Canadian Swine Improvement Program (Canadian Centre for Swine Improvement, 2015).

3. Carcass and Pork Quality Attributes

Carcass attributes can affect the costs to the packers and processors. A large factor is simply the carcass weight since larger weights result in more pork to sell for the fixed costs associated with slaughter and processing of an individual hog. However, the quality of the carcass is also important. As noted earlier, effective selection for lean growth over many decades has been important to allow for heavier carcass weights. Without that selection, heavier hogs would mostly have resulted in additional fat on the carcass. It takes a lot of energy to put on fat compared to lean and the extra fat adds relatively little value to the carcass.

Selecting for lean growth and feeding to genetic potential has been effective in the past where the focus has been primarily on efficient production of lean pork. However, as we look to the future, other attributes related to quality of both carcass and final pork products

are getting more attention. Nutrition and genetics offer some great opportunities to influence many of these attributes. Some examples will follow to illustrate, but the principles can be applied to any attribute that could be targeted to increase net value of the pork being produced.

Some decisions made by producers can have large effects on carcass value. For example, lowering feed costs by including relatively high levels of inexpensive dried distiller's grains (DDGS) can have some negative impacts on pork quality. Genetic selection for lean growth and feed efficiency can also result in correlated changes in muscle metabolism, fatty acid profile and proportion of different muscle fiber types. Although pork quality may not affect what a producer will be paid today, lower quality will affect the value further along the pork chain. This will put buyers of the hogs in a weaker competitive position to buy more hogs in the future.

One possibility is to work on genetic selection for hogs that maintain pork quality with less costly feed ingredients. However, there will be limits, especially in the short term, on what genetics can do to compensate for adverse effects of feed ingredients on quality. Similarly, feeding strategies might partly compensate for adverse effects on pork quality resulting from selection for lean growth. Other feeding strategies may enhance pork quality but could add some cost for the producer. It is therefore important to understand the effects of feeding and genetics on pork quality and to find ways to motivate producers to consider pork quality in both their feeding strategies and genetic choices. In the simplest case, nutritional strategies can help to target specific quality of pork, for example limiting the amount of DDGS. In some cases, a combination of genetics and nutrition might be more effective for particular pork quality attributes. In other cases, genetics might offer the tool to enhance pork quality without requiring any nutritional or other changes by the producer.

EXAMPLES OF WAYS TO INCREASE NET CARCASS VALUE

1. Feeding to Genetic Potential

Feeding to genetic potential may not be as easy as one would think. The challenge with this is that it is always a moving target. In part this is because breeding stock is continually improving, even if you don't change your genetic supplier. Genetic suppliers are always working to make genetics even better, so last year's optimal feeding program may not be optimal today. However, even more significant than changes in genetics are changes in environment. Some of these changes may be deliberate management changes, some could be unplanned large changes such as a disease break or weather conditions, and others could be much more subtle but still very important. It really becomes a challenge of feeding to the combination of genetic and environmental potential. Your nutritionist and your genetic supplier can provide some guidelines. You may also consider some on-farm trials and use of a program such as PorkMaster® to manage a feeding program with continuous assessment and improvement. Such an approach has been shown to save \$2 to \$5 per pig in feed costs while at the same time enhancing carcass value (Simpson, 2009).

2. Selection of Genetics for Lean Yield

The relative amount of fat versus lean tissue in pigs is quite heritable and selection over many decades has dramatically increased lean yield in today's market hogs. Yet there still

remains significant variability in lean yield and hence some opportunity to further increase carcass value. In most cases, higher lean yield means more value. However, there are also opportunities where a more moderate level of lean is desirable. In other words, targeting specific levels of lean yield (not just maximum) is important.

Side by side comparisons among sire lines have shown differences in lean yield as much as 2.29% (Fortin, 2013). Although differences among most sire lines would be smaller than this, there may be opportunity to work with your existing genetic supplier to choose terminal line semen that is targeted to specific levels of lean yield. This can be done by creating pools of boars based on their genetic evaluation for lean yield. For example, looking at commercially available semen from Durocs evaluated on the Canadian Swine Improvement Program, the difference between a pool from the highest 10% and lowest 10% ranked on lean yield would make a difference of almost a full 1% in grading lean yield for the market hog.

This flexibility could help producers to optimize lean yield to match a particular grading grid. For packers it gives flexibility to increase the amount of lean if that is desired (+1% would give an extra kg of lean pork per carcass) or to produce cuts with lower levels of lean, for example for higher value fresh pork markets. With this approach, it isn't necessary to change genetic suppliers or to give up other things that you may like with your current choice of sire line.

Note that these just happen to be the currently available crop of boars with semen available and they were not selected specifically to provide a large range of lean yield. Where there is value to target higher or lower levels for a trait such as lean yield, new boars coming into service could be selected with this in mind. The same principle can be applied to other traits such as marbling, colour and firmness. All that is needed is motivation for genetic suppliers to evaluate these traits.

3. Targeting Other Traits Related to Carcass Value

Previous research has demonstrated that there is lots of variability for carcass and meat quality traits and a significant proportion of this is related to genetics (Ciobanu et al., 2011). As we saw for lean yield, side by side comparisons among sire lines have shown significant differences in other carcass and meat quality traits (Fortin, 2013). Again, as shown earlier for lean yield, there is untapped potential to select within lines to create boar pools to target various levels of these other traits. These genetic choices could be combined with nutrition and other management strategies to target more precisely specific pork quality attributes.

However, despite the potential to change carcass and meat quality traits, the market place for the most part has offered little incentive to focus on these traits up until now. Most carcass and meat quality traits are also challenging and expensive to evaluate since they can only be measured after slaughter. It also isn't practical in high speed commercial packing plants to keep track of individual animals and it is too disruptive to take special measurements by conventional methods on a routine basis.

Nevertheless, in spite of the past and the challenge to measure these traits, today there is increasing interest to focus more on carcass and meat quality. In fact, Canadian producers and packers are now supporting a domestic marketing strategy which includes a focus on

quality of Canadian pork (Canada Pork, 2015). There are already important markets for Canadian pork that pay high premiums for quality, such as the Japanese market. The Canadian domestic marketing strategy is focused on an opportunity to provide higher quality for a premium price here in Canada. Enhanced quality will also create more opportunity for higher value in export markets.

At the same time as we are seeing increased interest in pork quality, new technologies are opening the door to more easily take measurements on pork quality traits (Swine Innovation Porc, 2015). Further, developments in genomics are also making it practical to evaluate and select for these kinds of traits (Swine Innovation Porc, 2012). Some of the key traits include pork colour, marbling and firmness. Once we have evaluations on these and other traits, like in the example for lean yield above, pools of boars can be identified that target specific levels for these specific traits.

4. Combining Nutrition and Genetics to Increase Marbling

Marbling is an interesting trait to use as an example for multiple reasons. For one, it is a trait that is recognized by buyers of our pork and by consumers. There are some fresh pork markets that pay large premiums for higher marbling while other markets such as processed meats want less marbling. Second, marbling levels vary considerably but in general are thought to be too low for the fresh pork market in the majority of market hogs. Third, marbling levels are quite highly heritable and can also be influenced by nutrition. And fourth, we can now measure marbling levels in live pigs using ultrasound. From live measurements we can provide genetic evaluations on commercial sires, giving producers a powerful tool to target specific marbling levels.

The Canadian Centre for Swine Improvement recently completed a project to demonstrate the potential to increase marbling in commercial hogs through a combination of nutrition and genetics (Maignel et al., 2014). Two feeding formulations and two groups of Duroc boars were evaluated. The 2x2 design included the normal feeding formulation used in the test facilities involved and a second one adapted to lower protein (and lysine) and increased energy towards the end of the finishing period. The two groups of boars were selected for low or high genetic potential for marbling. Genetic potential was based on the genetic evaluations of commercially available Duroc sires on the Canadian Swine Improvement Program. The effects of nutrition and genetics were similar and the combination resulted in a difference of about 1% intramuscular fat (or marbling) in the crossbred commercial hogs. However, the change in the feeding formulation also resulted in significantly more fat, less lean and slower growth. On the other hand, there were no significant differences for these other traits between the boar groups selected for high or low marbling.

The conclusion from this project was that nutrition and genetics both provide tools to significantly influence marbling. However, genetics was particularly interesting in that it appears you can target higher marbling without adversely affecting other important traits. Note also that the boars in this trial were selected from among the ones currently available at the time of the trial. They were not specifically selected to go into service based on marbling evaluations. There is much more potential to increase the average level of marbling through genetic selection and also to increase the range of marbling levels available by considering this trait when new boars are selected to enter service.

CONCLUSIONS

Nutritional and genetic strategies individually and in combination offer tools to influence carcass value in many ways. As our knowledge and technologies develop, these tools are becoming more and more powerful. However, a bigger challenge is to determine the attributes of the carcass where changes or specific targeted levels can add more value. The additional value could come anywhere in the pork production chain, but there is a need to motivate changes at one point in the chain when the increased value takes place somewhere else in the chain. For example, if genetic suppliers worked to provide sires with higher genetic potential for marbling, this could give producers the tool to produce more pork that meets the requirements of high value fresh pork markets such as in Japan and in new premium branded markets here in Canada. Feeding strategies can also affect attributes such as firmness of the pork and marbling. However, such decisions also need to consider costs related to changing specific attributes of the carcass. In the case of nutritional changes, the producer is directly affected and a change could have a large effect on cost of feeding. A change in feeding program can also adversely affect important traits other than the one being targeted. The benefit needs to be at least as large as the cost and there needs to be a way for producers to cover the cost. The costs of genetic changes, in contrast, don't affect the commercial producer directly, since the breeding stock suppliers are doing the work, and the cost per commercial hog would be very small. There is potential for large benefits from genetics with relatively little cost, but there needs to be a way for breeding stock suppliers to cover these costs. Feeding to genetic potential and selection of genetics for lean yield are examples that have provided opportunities for large increases in net carcass value in the past and continue to provide more opportunities today. Much of the benefit relates to lowering costs of production, slaughter and processing, but there is also increased market hog value for both the producer and the packer. There is potential today to start to work on targeting other traits related to pork quality that can further increase carcass value.

Genetic and nutritional strategies can both be helpful, but two important developments are happening that open the door to make this a reality: 1. The domestic marketing strategy focussed on increasing value of the final pork products; and 2. New technologies to make it practical to predict and measure pork quality traits on both the live animal and in commercial packing plants. Marbling is a particularly interesting example where we know this is important for premium markets and we already have tools in place to control the level of marbling in pork. What is presented here is intended to provide practical and realistic examples of opportunities to increase carcass value. However, the principles can be applied to influence other attributes of the carcass which the industry may determine could bring additional value.

ACKNOWLEDGEMENTS

Agriculture and Agri-Food Canada (AAFC) provided funding through the Canadian Agricultural Adaptation Program for research on the impact of genetics and feeding on loin marbling levels of Canadian hogs. Swine Innovation Porc with support from AAFC's Science Cluster Program and provincial pork organizations has provided financial support for research on development of new genomic tools to improve meat quality traits and production efficiency in pigs and also use of novel technologies to optimize pig performance, welfare and carcass value. The provincial department of agriculture in

Quebec (MAPAQ) also provided some financial support. Many industry partners including breeders, producers, packers and regional swine improvement centres, as well as researchers at AAFC and Canadian universities also supported and collaborated in these projects.

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